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SUBSTRATE RETAINING APPARATUS AND EXPOSURE APPARATUS USING THE SAME

BACKGROUND OF THE INVENTION

The present invention relates generally to a substrate retaining apparatus suitable for a variety of manufacturing apparatuses used in a photolithography process of manufacturing a micro device such as, e.g., a semiconductor device, a liquid crystal display device, an imaging device (CCD, etc.), a thin film magnetic head, etc., and more particularly to a substrate retaining apparatus for holding a photosensitive substrate that is applied to an exposure apparatus for transferring a mask pattern onto a photosensitive substrate (such as a semiconductor wafer or a glass plate of which a surface is formed with a photo resist layer).

The present invention relates also to an exposure apparatus for manufacturing the micro device as described above.

Background Art

Over the recent years, in an exposure apparatus for manufacturing a semiconductor device such as a semiconductor circuit device, etc., what has hitherto been used as a wafer holder (wafer chuck) for holding a wafer has such a configuration that a base material thereof is composed of porous ceramic, and a wafer placing surface is coated comparatively thick and, after the

coating, subjected to final surface finishing.

A scheme in this type of conventional wafer holder is to let the heat evolved by an exposure of the wafer escape promptly downward of the wafer holder. For attaining this, a material exhibiting a high heat conduction is selected as a base material of the wafer holder.

It is, however, a recent trend that a heat quantity of the wafer when irradiated with exposure light becomes increasingly large. However high heat conduction the material used as the base material may have, the holder swells and deforms before the heat escapes outside the holder, and besides it might turn realistic that the wafer mounted on the holder resultantly expands.

Moreover, in the conventional wafer holder described above, the final surface finishing is carried out after the coating process as explained above. A coating layer of the conventional wafer holder is, though comparatively thick, on the order of several tens of μm at the maximum in thickness, and the final surface finishing is hard enough to require an extreme precision.

On the other hand, in the photolithography process defined as one of processes of manufacturing the semiconductor device, a projection exposure apparatus (stepper) for projecting in reduction the mask pattern onto a shot region on the wafer, is often used as an exposure apparatus for transferring the pattern formed

on the mask or a reticle onto the wafer (photosensitive substrate) coated with a photo resist. What has been developed and utilized as a stepper may be categorized into a step-and-repeat type of exposing batchwise the shot region on the wafer to the light via the mask pattern, and repeating the batchwise exposure of other shot regions by sequentially moving the wafer, and a step-and-scan type, provided recently in terms of enlarging an exposure range and enhancing an exposure performance, of scanning and illuminating the shot region on the wafer with a beam of slit light taking a rectangular or other shape by synchronously moving the mask and the wafer, thus sequentially exposing the shot regions, and repeating the scan/exposure processes for other shot regions by sequentially moving the wafer.

In those types of exposure apparatuses, the wafer as an exposure target is sucked and held by a wafer holder placed on a wafer table. A fiducial mark member formed with fiducial marks for measuring a fluctuation quantity of a baseline is integrally fixed onto the wafer table. Further, the wafer table is positioned and moved in X- and Y-directions (in biaxial directions within the plane substantially orthogonal to the optical axis of a projection optical system) by a linear motor, etc., and a movable mirror (reflection mirror) of a laser interferometer for detecting a position of the wafer table is integrally fixed onto the wafer table. Note that the

baseline is a baseline for alignment that is prescribed by an off-axis type alignment sensor, or implies a distance between an exposure position and an alignment position based on the baseline.

As described above, the recent trend is that there increases the heat quantity, i.e., the irradiation power of the exposure light when wafer on the wafer table is irradiated with the light. Therefore, a relative positional relationship between respective members changes due to an occurrence of warp caused by a difference in thermal expansion coefficient between the members as well as to deformations, caused by the thermal expansions, of the wafer table and the various members provided on this wafer table, with the result that errors contained in various measured values. These factors lead to a problem, that there is a case where the mask can not be transferred with a high accuracy and a micro device with a high-quality and high-reliability can not be manufactured.

SUMMARY OF THE INVENTION

It is a first object of the present invention to provide a substrate retaining apparatus capable of preventing an expansion or a deformation even when irradiation heat evolves when in an exposure process.

It is a second object of the present invention to provide a substrate retaining apparatus capable of

facilitating a working process.

It is a third object of the present invention to provide an exposure apparatus capable of manufacturing a micro device having a high-quality and a high-reliability even when irradiation power of exposure light increases.

The present invention does not stick to the prior art concept that the irradiation heat produced by the irradiation of the exposure light is made to promptly escape, and aims at accomplishing the above objects by selecting materials that neither expand nor deform even when the irradiation heat evolves.

To accomplish the first and second objects given above, according to a first aspect of the present invention, a substrate retaining apparatus comprises a base material involving use of low thermal expansibility ceramic of which a thermal expansion coefficient is 0 - 0.5 ppm at a normal temperature, and a coating material having a larger hardness than the base material and coated over the base material after effecting surface finishing of the base material in a predetermined configuration.

According to the first aspect of the present invention, after the surface finishing of the base material, the finishing work of the coating material is not executed. It is therefore feasible to facilitate the working of the substrate placing surface and enhance a degree of flatness of this surface. Further, in an

exposure apparatus used in a photolithography process for manufacturing a micro device, even if the heat is accumulated in the substrate retaining apparatus through a photosensitive substrate when irradiated with the exposure light, the substrate placing portion shows almost no thermal expansion. Accordingly, while the mask pattern is sequentially transferred onto each of a plurality of segment regions on the photosensitive substrate by a step-and-repeat method (which is known as a step-and-scan method in a scan type exposure apparatus), the thermal deformation of the photosensitive substrate can be substantially restrained. Therefore, the mask pattern can be highly accurately aligned with each of the plurality of segment regions, and, when transferring the pattern formed in each segment region in overlap with the mask pattern, these two patterns can be overlapped precisely over their entire surfaces. Further, when transferring a plurality of mask patterns patched together on the photosensitive substrate, the plurality of mask patterns can be accurately connected together.

According to a second aspect of the present invention, a substrate retaining apparatus comprises a base material composed of low thermal expansibility ceramic and having a substrate placing surface, and a coating material having a difference in thermal expansion coefficient from that of the base material, the difference being equal to 5 ppm or smaller, the coating material being

coated over the substrate placing surface after working the substrate placing surface. The working of the substrate placing surface can be therefore facilitated, and the degree of flatness thereof can be enhanced. Moreover, in the exposure apparatus, it is feasible to align the mask pattern with the photosensitive substrate, align the mask pattern with the segment region (pattern) on the photosensitive substrate or accurately patch the plurality of mask patterns together on the photosensitive substrate. Further, it is discovered that if the difference in the thermal expansion coefficient between the base material and the coating material exceeds 5 ppm, the base material is hard to be coated with a coating material, and it follows that a coating material having a difference in the thermal expansion coefficient from the base material is equal to 5 ppm or smaller. It is therefore possible to prevent a problem of being unable to apply the coating material on the substrate placing surface of the base material composed of the low expansibility ceramic.

The substrate retaining apparatus according to a still further aspect of the present invention is suited especially to an exposure apparatus for transferring a mask pattern into a photosensitive substrate. The substrate retaining apparatus for sucking and holding the photosensitive substrate is provided on a stage for relatively moving the photosensitive substrate with

respect to the mask.

To accomplish the third object given above, an exposure apparatus according to the present invention in which a substrate holder and a fiducial member formed with a fiducial mark are disposed on a substrate table, and a pattern image of a mask illuminated with light from an illumination optical system, is projected through a projection optical system onto a photosensitive substrate held by the substrate holder, is characterized in that, the substrate table, the substrate holder and the fiducial member are composed of low thermal expansibility materials of which thermal expansion coefficients are substantially equal to each other.

In the exposure apparatus according to the present invention, the substrate table, the substrate holder and the fiducial member are composed of the low thermal expansibility materials, and hence, even when a temperature rises due to a heat emission with the irradiation of the exposure light, the substrate table, the substrate holder and the fiducial member themselves have small thermal expansions. Besides, there is a small change in terms of positional relationship between those members. Further, the substrate table, the substrate holder and the fiducial member are composed of low thermal expansibility materials of which thermal expansion coefficients are substantially equal to each other, so that there might be reduced an occurrence of warp caused

by differences in the thermal expansion coefficient between the substrate table and between the substrate table and the fiducial member. Accordingly, changes in relative dimensions between the members and deformations of the respective members decrease, and, even when the temperature rises due to the heat absorption with the irradiation of the exposure light, the pattern can be transferred with a high accuracy. More essentially, it is possible to manufacture the micro device exhibiting a preferable characteristic and a high quality.

It is desirable that the low thermal expansibility ceramic used in the present invention be super precision glass ceramic or cordierite-series ceramic material or alumina-series ceramic. Herein, the super precision glass ceramic is composed of a crystallizing phase and a glass phase, and preferable glass ceramic is, for example, Zerodur (trade name) made by Shot Corp. which contains 70 - 78 % by weight of the crystallized phase taking a high quartz structure. Moreover, the coating material is preferably DLC or TiC or TiN, and a coating thickness thereof is preferably 1 - 10μm.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view showing a whole configuration of a wafer holder in a first embodiment of the present invention;

FIG. 2 is an enlarged view of an A-portion in FIG.

1;

FIG. 3 is a view schematically showing a whole construction in a second embodiment of the present invention;

FIG. 4 is a perspective view showing principal components in the second embodiment of the present invention; and

FIG. 5 is a perspective view showing principal components in a third embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will hereinafter be described with reference to the accompanying drawings.

FIG. 1 is a perspective view showing an external configuration of a wafer holder 1 in a first embodiment of substrate retaining apparatus of the present invention. The entire external configuration of the wafer holder 1 is substantially the same as what has hitherto been known. To be specific, a body 2 of the wafer holder 1 may be defined as a plate member constructed having a substantially circular side portion 2b excluding its flat side portion 2a formed in a part of this body 2, and an upper surface serves as a wafer placing surface 3. The wafer placing surface 3 is formed with a multiplicity of grooves 4 concentric with each other, for sucking and holding a wafer (unillustrated) onto the wafer holder 1. Each

groove 4 is, as shown in FIG. 2, defined by two stripes of protruded portions 4a, 4b adjacent to each other as illustrated in FIG. 2, and communicates with a negative pressure source from the underside (a lower surface) of the holder via holes (not shown) properly formed in the body 2. Thus, the wafer is sucked and held over almost entire area of the wafer placing surface 3 of the wafer holder 1, and can be corrected in plane.

As shown partially in enlargement in FIG. 2, the surface of the body 2 of the wafer holder 1 is provided with a coating layer 5.

As explained above, a base material constituting the wafer holder body has hitherto been selected in consideration of letting the heat evolved by irradiating the wafer placed on the wafer holder with the exposure light escape downwardly of the wafer holder via the body of the wafer holder. In accordance with this embodiment, however, there is selected low thermal expansibility ceramic having a thermal expansion coefficient (linear expansion coefficient) of 0 - 0.5 ppm. This low thermal expansibility ceramic may be exemplified by glass ceramic or cordierite-series ceramic or alumina-series ceramic. Among those ceramics, the preferable glass ceramic may be super precision glass ceramic classified as no-cavity inorganic, assuming a mixed state of a crystallized phase and a glass phase, and containing 70 - 78% of the crystallized phase taking a high-quartz structure, which

is commercially available as, e.g., Zerodur (trade name). Note that a linear expansion coefficient of Zerodur can be decreased down to zero and further to a minus value.

The ceramic base material exhibiting the low thermal expansibility is finished in a predetermined shape as a wafer holder, and thereafter coated uniformly with a material having a larger hardness than the ceramic over the entire area serving as the wafer placing surface.

According to tests, it is not preferable that a difference in the thermal expansion coefficient between the coating material and the base material exceeds 5 ppm.

Further, a preferable coating layer exhibits a high conductivity in order to prevent a static electricity from being generated on the wafer holder.

In the case of the base material used in the present embodiment, for instance, DLC or TiC or TiN is preferable as the coating material, and its thickness of 1 - 10 μm may suffice. A CVD (Chemical Vapor Deposition) method may be preferable as the coating method.

The thermal expansion or a thermal deformation of the wafer holder in this embodiment is small irrespective of an emission of heat due to the light striking on the wafer, and therefore a high-accuracy exposure can be attained regardless of an increase in quantity of the heat evolved due to a rise in irradiation energy of the exposure light.

Further, in this embodiment, the linear expansion

coefficient of the low thermal expansibility ceramic chosen as the base material is set to 0 - 0.5 ppm. There exists, however, the materials of which the linear expansion coefficient can be decreased down to a comparatively small minus value as in the case of, e.g., Zerodur. Hence, a requirement of the low thermal expansibility ceramic preferable as the base material is that an absolute value of the linear expansion coefficient thereof may be 0.5 ppm or less.

Moreover, in this embodiment, the material exhibiting the larger hardness than the base material is used as the coating material. A material, even if its hardness is equal to or smaller than the base material, may be used as the coating material on condition that a difference (absolute value) between base material and this material is under approximately 5 ppm. This is because the coating over the base material becomes extremely difficult if the difference in the linear expansion coefficient therebetween exceeds 5 ppm.

Further, in accordance with this embodiment, the base material is formed with the wafer placing surface on which the surface finishing is done, and thereafter the wafer placing surface is simply coated with the coating material. Namely, there is no necessity for executing the surface finishing of the coating layer formed on the wafer placing surface. This facilitates the working of the wafer holder and enables the coating

layer to decrease in thickness. Note that the coating layer may be formed on only at least contact portions (e.g., upper edge surfaces of the protruded portions 4a, 4b in FIG. 2) with the wafer, of the wafer placing surface. If considering an adhesion of foreign matters, however, it is desirable that the coating layer be formed over the whole wafer placing surface.

Further, the thickness of the coating layer formed on the base material may be increased to, e.g., 30 - 50 μm, and the surface finishing of this coating layer may be thus carried out. In this case, there is no necessity for performing the surface finishing of the base material.

Moreover, the protruded portion on which the wafer is placed is not limited to the annular shape (concentric shape) as illustrated in FIG. 1 but may take any configurations. In a scan type exposure apparatus (e.g., a scanning stepper) for transferring a mask pattern onto the wafer by moving the mask and the wafer in synchronization, it is also possible to use what a plurality of linearly protruded portions extending in a direction orthogonal to a scan direction (moving direction) of the wafer, are arranged at predetermined spacings in the moving direction.

Further, the present invention can be also applied to a so-called pin chuck holder formed with a multiplicity of pin-shaped protruded portions.

The present invention becomes more effective if

using the wafer holder described above, and if the material of which the thermal expansion coefficient is approximate to zero is used for a moving mirror for a positional detection as well as for an XY table for sustaining the wafer holder.

The embodiment discussed above has exemplified the wafer holder provided on the stage for relatively moving the semiconductor wafer with respect to the mask in the exposure apparatus for transferring the mask (or reticle) pattern onto the semiconductor wafer. The present invention can be, however, applied to the substrate retaining apparatus for retaining a glass plate formed with, e.g., a liquid crystal display or a ceramic wafer formed with a thin film magnetic head in addition to the semiconductor wafer.

Moreover, the substrate retaining apparatus of the present invention is suited to the exposure apparatus (such as a mirror projection aligner, a stepper, a scanning stepper, etc.) used in the photolithography process for manufacturing a micro device such as a semiconductor device, a liquid crystal display device, an imaging device (CCD) or the thin film magnetic head. Other than what is given herein, the present invention can be applied to a variety of manufacturing apparatuses used in the photolithography process, e.g., a laser repair apparatus for cutting a fuse by irradiating the fuse of a circuit pattern formed on the semiconductor wafer with

laser beams.

It should be noted that the illumination light for exposure which is used for the stepper and the scanning stepper may be any one of emission lines (e.g., g-line, i-line) emitted from a mercury lamp and higher harmonics of a KrF excimer laser (wavelength: 248 nm), an ArF excimer laser (wavelength: 193 nm), an F2 excimer laser (wavelength: 157 nm) or a YAG laser. Further, the substrate retaining apparatus of the present invention can be also applied to a EUV exposure apparatus including a reduction projection optical system constructed of only a plurality of reflection optical elements (mirrors), wherein EUV (Extreme Ultra violet) rays having an oscillation spectrum in, e.g., 5 - 15 nm (soft X-ray region) are used as the exposure illumination light, an illumination area on a reflection mask is defined in a circular-arc slit shape, and a pattern of the reflection mask is transferred onto the wafer by moving the reflection mask and the wafer in synchronization at a velocity ratio corresponding to a magnification of the reduction projection optical system.

The substrate retaining apparatus of the present invention has no problems in terms of expansion and deformation irrespective of the increase in the irradiation energy of the exposure light.

Moreover, in the substrate retaining apparatus of the present invention, the final configuration finishing

process for obtaining a degree of flatness of the wafer placing surface of the wafer holder may be carried out before forming the surface coating layer, thereby facilitating the configuration finishing work. Further, the coating layer may therefore be as thin as 1 - 10μm.

Next, one embodiment of the exposure apparatus according to the present invention will be discussed.

FIG. 3 is a view schematically showing a construction of the reduction projection type exposure apparatus of a step-and-repeat system by way of the embodiment of the exposure apparatus of the present invention. FIG. 4 is a perspective view showing the principal portions thereof in enlargement.

Referring to FIG. 3, an illumination optical system 11 comprises an light source for emitting excimer laser beams, an optical integrator (homogenizer) such as a fly-eye lens or rod integrator for homogenizing an illuminance distribution, an illumination system aperture stop, a reticle blind (variable field stop) and a condenser lens system. A reticle R as a photo mask formed with a pattern to be transferred is sucked and held on a reticle stage 12, and is irradiated with a beam of exposure light IL emitted by the illumination optical system 11.

An image of the pattern within the illumination region of the reticle R is projected on the surface of the wafer W coated with a photo resist as an exposure target

at a reduction magnification of $1/\alpha$ (α is, e.g., 5 or 4) through a projection optical system PL. The following discussion will be made on the assumption that a Z-axis is given in parallel to an optical axis AX of the projection optical system PL, an X-axis is given in parallel to the sheet surface in FIG. 3 within the plane perpendicular to the Z-axis, and a Y-axis is given perpendicularly to the sheet surface in FIG. 3.

The reticle stage 12 positions the reticle R sucked and held on the reticle stage 12 within the XY plane. A position of the reticle stage 12 is measured by an unillustrated laser interferometer, and an operation of the reticle stage 12 is controlled based on this measured value and control data given from a main control system 13. On the other hand, the wafer W is held by vacuum suction on a wafer holder (substrate holder) WH. This wafer holder WH is likewise sucked by vacuum onto a wafer table (substrate table) 14 and thus detachably held. The wafer table 14 is installed through a plurality of actuators which displace in a direction Z on an XY stage 15.

The wafer table 14 controls a focal position of the wafer W by an auto focus method and also a tilt angle, thereby aligning the surface of the wafer W with an image surface of the projection optical system PL. Further, the XY stage 15 is installed through a linear motor on a base 16, and positions the wafer table 14 (wafer W) in

X- and Y-directions. A movable mirror (reflection mirror) 17 of the laser interferometer is fixed to the wafer table 14, and X- and Y-coordinates and an angle of rotation of the wafer table 14 are measured by the movable mirror 17 and the laser interferometer (main body) 18 disposed facing to the movable mirror 17. Those measured values are supplied to the stage control system 19 and the main control system 13. The stage control system 19, based on the measured values by the laser interferometer 18 and the control data given from the main control system 13, controls an operation of the linear motor of the XY stage 15.

The wafer holder WH, a fiducial mark member FM and the movable mirror 17 (17X, 17Y) each composed of a low thermal expansible material which will be mentioned later on, are provided on the wafer table 14.

The movable mirror 17 is, as shown in FIG. 4, constructed of the movable mirror 17X for measuring a position in the X-axis direction, and the movable mirror 17Y for measuring a position in the Y-axis direction. The movable mirror 17X is integrally fixed to an upper edge portion of the wafer table 14 by fastening, e.g., screws so that a longitudinal direction of the mirror 17X is set along the Y-axis in a state of its mirror surface being oriented in a +X direction. The movable mirror 17Y is likewise fixed thereto so that a longitudinal direction thereof is set along the X-axis in a state of its mirror

surface being oriented in a +Y direction.

The wafer holder WH is a member taking a substantially disk-like shape, and detachably held by vacuum suction in a predetermined position on the wafer table 14. A multiplicity of recessed grooves, substantially concentric with each other, for sucking and holding the wafer W, are formed in the wafer placing surface, i.e., the upper surface of the wafer holder WH. Each groove communicates with an unillustrated negative pressure source via holes perforated in a plate thicknesswise direction of the wafer holder WH. Further, the wafer holder WH is formed with a plurality of through-holes (not shown) that three pieces of vertical movement pins enter, these pins constituting a wafer vertical moving mechanism for supporting the wafer W at three points when replacing the wafer and moving the wafer W up and down. The wafer W is placed on the wafer holder WH by this wafer vertical moving mechanism, and the negative pressure source is operated, whereby the wafer W is sucked and held on the placing surface of the wafer holder WH and can be corrected in plane.

The wafer holder WH becomes preferable if constructed as the substrate retaining apparatus in the way described above referring to FIGS. 1 and 2.

The fiducial mark member FM is integrally fixed in the vicinity of the wafer holder WH on the wafer table 14 by fastening the screws. The fiducial mark member FM

is composed of a light transmissive member, of which the upper surface is formed with a pair of fiducial marks 20A, 20B disposed at a predetermined interval in the X-direction and each taking a cross-shape. Further, an illumination system for illuminating the fiducial marks 20A, 20B with the illumination light divided from the exposure light IL, is provided on the side of the projection optical system PL under the fiducial mark member FM on the wafer table 14. When aligning the reticle R, the fiducial marks 20A, 20B are positioned so that center between the fiducial marks 20A, 20B on the fiducial mark member FM is substantially aligned with the optical axis AX of the projection optical system PL by moving the XY stage 15.

Further, two alignment marks 21A, 21B each assuming, as one example, a cross shape, are formed so that a pattern region of the pattern surface (lower surface) of the reticle R is interposed in the X-direction between these two alignment marks. A spacing between the fiducial marks 20A, 20B is set substantially equal to a spacing between reduced images of the alignment marks 21A, 21B through the projection optical system PL. As described above, in the state where the center between the fiducial marks 20A, 20B is substantially aligned with the optical axis AX, the fiducial marks 20A, 20B are illuminated with the illumination light having the same wavelength as the exposure light IL from under the fiducial mark member FM,

whereby the enlarged images of the fiducial marks 20A, 20B through the projection optical system PL are formed in the vicinities of the alignment marks 21A, 21B of the reticle R.

Mirrors 22A, 22B for reflecting the illumination light traveling from the projection optical system PL in the $\pm$X directions, are disposed upwardly of the alignment marks 21A, 21B. Then, alignment sensors 23A, 23B based on an image processing method are provided in a TTR (Through-The-Reticle) system so as to receive the beams of illumination light reflected by the mirrors 22A, 22B. Each of the alignment sensors 23A, 23B includes an image forming system and a two-dimensional imaging device such as a CCD camera, etc.. The imaging device images the alignment marks 21A, 21B and the fiducial marks 20A, 20B corresponding thereto, and imaging signals thereof are supplied to an alignment signal processing system 24 in FIG. 3.

The alignment signal processing system 24 executes image process of the imaging signals, thereby obtaining X- and Y-directional positional deviation quantities of the alignment marks 21A, 21B from the images of the fiducial marks 20A, 20B. Then, the alignment signal processing system 24 supplies these two sets of positional deviation quantities to the main control system 13. The main control system 13 positions the reticle stage 12 so that those two sets of positional deviation quantities

fall in symmetry with each other within a predetermined range. With this processing, the alignment marks 21A, 21b, more essentially, the intra-pattern-region pattern of the reticle R can be positioned with respect to the fiducial marks 20A, 20B.

In other words, the center (exposure center) of the reduced image of the pattern of the reticle R through the projection optical system PL, is positioned substantially at the center (substantially the optical axis AX) between the fiducial marks 20A, 20B, and sides, orthogonal to each other, of the outline (outline of the pattern region) of the pattern, are set parallel to the X- and Y-axes. In this state, the main control system 13 in FIG. 1 stores X- and Y-directional coordinates of the wafer table 14 which are measured by the laser interferometer 18, thereby finishing the alignment of the reticle R. Thereafter, an arbitrary point on the wafer table 14 can be shifted to the exposure center of the pattern.

Further, referring to FIG. 3, the side surface of the projection optical system PL is provided with an alignment sensor 25 of the image processing system on the basis of an off-axis method in order to detect the mark position on the wafer W. The alignment sensor 25 illuminates a subject mark with the illumination light that is non-photosensitive to the photo resist and has a broad band, and the subject mark is imaged by the two-dimensional imaging device such as the CCD camera,

etc.. Then, an imaging signal thereof is supplied to the alignment signal processing system 24. A spacing (baseline quantity) between a detection center of the alignment sensor 25 and a center (exposure center) of the projection image of the pattern of the reticle R, is obtained by use of the fiducial marks on the fiducial mark member FM, and stored in the main control system 13.

The alignment marks of the wafer W sucked and held on the wafer holder WH, are measured by use of the unillustrated alignment sensor for the wafer, and the alignment is effected with respect to the whole thereof or each shot region. Then, the exposure target shot region on the wafer W is sequentially located in an exposure position, and thereafter the pattern region of the reticle R is irradiated with the exposure light IL such as the excimer laser beams emitted from the illumination optical system 11, whereby an image obtained by reducing the pattern within the pattern region at a reduction magnification of $1/\alpha$, is transferred onto the shot region. After the reduced image of the pattern has been thus transferred by exposure onto each shot region on the wafer W, then the transferred image on the wafer W is developed, and the process such as etching, etc. is executed , thereby forming a circuit pattern of a layer having the semiconductor device in each shot region on the wafer W.

Herein, the wafer table 14, the wafer holder WH,

the fiducial mark member FM and the movable mirrors 17A, 17Y are composed of the same material exhibiting an extremely small thermal expansion coefficient. In this embodiment, the low thermal expansibility ceramic of which the thermal expansion coefficient (linear expansion coefficient)is 0.1 ppm or under is used as the material showing the low thermal expansibility. A material with the thermal expansion coefficient of 0.5 ppm or smaller may be, however, used as in the first embodiment. Glass ceramic or cordierite-series ceramic or alumina-series ceramic can be adopted as this low thermal expansibility ceramic.

In the case of using the glass ceramic among. those ceramics, there may be adopted the super precision glass ceramic assuming the mixed state of the crystallized phase and the glass phase, and containing 70 - 78% of the crystallized phase taking a high-quartz structure, which is commercially available as, e.g., Zerodur (trade name). It is because the glass phase exhibits a plus thermal expansibility, while the crystallized phase exhibits a minus thermal expansibility, and therefore the linear thermal expansion coefficient can be arbitrarily set with a specified temperature range, which involves adjusting a content quantity by properly controlling crystallizing conditions. Further, the thermal expansion coefficient can be minimized or reduced down to zero (or a minus value). The glass ceramic described above has no directivity and

includes the surface with no-cavity, of which chemical characteristics and a strength are substantially the same as those of the normal glass. Hence, the glass ceramic can be worked by use of the same machine and tools as those used for working the normal glass. The glass ceramic is advantageous in this aspect also.

Incidentally, with respect to the wafer holder WH, as described above referring to FIGS. 1 and 2, after the low thermal expansibility ceramic base material has been finished in the predetermined configuration, the entire portion serving as the wafer placing surface is uniformly coated with the material exhibiting the larger hardness than the ceramic. The preferable coating layer may be what exhibits a high conductivity in order to prevent the generation of the static electricity on the wafer holder WH. In the case of the base material in this embodiment, for instance, DLC or TiC or TiN is preferable as the coating material, and its thickness of 1 - 10 μm may suffice. The CVD (Chemical Vapor Deposition) method can be used as the coating method.

Further, each of the movable mirrors 17X, 17Y is manufactured in the following manner. An elongate plate-like base material is formed by using the ceramic material with the low thermal expansibility, and a portion serving as the mirror surface is polished with an extreme precision. Then, a material exhibiting a high light reflectivity such as silver and aluminum is vapor-

deposited by the vacuum evaporation method, etc., and the surface thereof is formed with a protect layer. Moreover, the fiducial mark member FM is manufactured in a way that follows. A tabular base material is formed by use of the low thermal expansibility ceramic material described above, the surface thereof is polished with the extreme precision. Then, one surface (upper surface) thereof is formed with the fiducial marks 20A, 20B each composed of a light-shielding thin film such as chrome by use of the photolithography method.

In accordance with this embodiment, each of the wafer table 14, the wafer holder WH, the fiducial mark member FM and the movable mirrors 17X, 17Y of the laser interferometer, is composed of the low expansibility material. Hence, even when the temperature rises due to the heat evolved with an irradiating absorption of the exposure light IL, there must be a small thermal expansion of each of the wafer table 14, the wafer holder WH, the fiducial mark member FM and the movable mirrors 17X, 17Y. Further, each of the wafer table 14, the wafer holder WH, the fiducial mark member FM and the movable mirrors 17X, 17Y, is composed of the same material, i.e., the material having the same thermal expansion coefficient. Accordingly, there decreases an occurrence of warp of each member due to the differences in the thermal expansion coefficient between the wafer table 14 and the wafer holder WH, between the wafer table 14 and the fiducial

mark member FM, and between the wafer table 14 and the movable mirrors 17X, 17Y.

Therefore, as for the wafer holder WH, though the wafer W is extremely firmly held by suction onto the wafer holder WH, the thermal expansion of the wafer holder WH itself is small, and hence there might a less possibility of causing the deformation of the wafer W with the thermal expansion of the wafer holder WH. Besides, even when the wafer W is forced to thermally expand with the irradiation of the exposure light IL, the wafer holder WH restricts this expansion, with the result that the deformation of the wafer W can be reduced. Further, with respect to the fiducial mark FM, positional fluctuations and the spacing between the fiducial marks 20A, 20B can be decreased, and, even when the temperature rises, the error of alignment can be reduced. Then, since the deformations of the movable mirrors 17X, 17Y are small, it is feasible to reduce an error of the measurement by the laser interferometer 18. Moreover, as to the wafer table 14, it is possible to decrease a change in the relative positions between the fiducial mark member FM, the wafer holder WH and the movable mirrors 17X, 17Y caused by the expansion thereof, and a variety of measurement errors can be also reduced.

As discussed above, in accordance with this embodiment, even when the temperature rises due to the heat evolved with the irradiating absorption of the

illumination light IL, the pattern can be transferred with the high accuracy, and more essentially the micro device with the preferable characteristics and high quality can be manufactured.

Note that the wafer table 14, the wafer holder WH, the fiducial mark member FM and the movable mirrors 17X, 17Y are not necessarily composed of the same material, and different materials may also be used if the thermal expansion coefficients thereof are substantially equal to each other.

Further, in the embodiment discussed above, the movable mirrors 17X, 17Y manufactured independently separately from the wafer table 14 are integrally fixed by fastening the screws. These independent movable mirrors 17X, 17Y may be, however, omitted, and, for example, as shown in FIG. 5, end surfaces (side surfaces) 14X, 14Y corresponding to the portions, provided with the movable mirrors 17X, 17Y, of the wafer table 17, are polished with the extreme high precision. Thereafter, the material exhibiting the high light reflectivity such as silver as well as aluminum is vapor-deposited thereon by the vacuum evaporation method, and protect layers are formed on the surfaces thereof, thereby attaining mirror surfaces. Since the thermal expansion coefficient of the wafer table 14 is extremely small, the integral construction described above can be attained, and it is possible to simplify the construction as well as to

enhance the accuracy.

Moreover, other construction may be adopted, wherein the end surface of the wafer table 14 is formed as a mirror surface, the movable mirrors 17X, 17Y are integrally manufactured, and besides, after working the upper surface of the wafer table 14, at least one of the wafer holder WH and the fiducial mark member FM is made integral.

It should be noted that the fiducial mark member FM is illuminated from under with the light, and hence at least regions formed with the fiducial marks 20a, 20B are contrived to transmit the light, however, if the alignment sensors 23A, 23B are constructed to illuminate respectively the fiducial marks 20A, 20B and the alignment marks 21A, 21B on the reticle R with the light, the whole fiducial mark member FM can be composed of the low thermal expansibility material in this embodiment.

Furthermore, the exposure target of the exposure apparatus to which the present invention is applied, is not limited to the semiconductor wafer but may, as a matter of course, include, e.g., a glass plate formed with a liquid crystal display and a ceramic wafer formed with a thin film magnetic head. In this case, at least a substrate holder for holding those substrates (glass plate, ceramic wafer) is set to a minus expansibility so as to offset the thermal expansion of the substrate, a deformation as a whole can be reduced.

Moreover, the projection exposure apparatus in FIG. 3 is classified as the step-and-repeat type reduction projection exposure apparatus. The present invention can be, however, similarly applied to a step-and-scan type reduction projection exposure apparatus. According to the step-and-scan type apparatus, the reticle R and the wafer W are synchronously scanned at a reduction ratio with respect to the projection optical system PL when the exposure is effected. Further, the present invention can be applied to a mirror projection aligner.

Note that the illumination light for exposure which is used for the stepper and the scanning stepper may be, as described in the first embodiment in FIGS. 1 and 2, any one of bright lines (e.g., g-line, i-line) emitted from the mercury lamp and higher harmonics of the KrF excimer laser (wavelength: 248 nm), the ArF excimer laser (wavelength: 193 nm), the F2 excimer laser (wavelength: 157 nm) or the YAG laser. Further, the present invention can be also applied to the EUV exposure apparatus including the reduction projection optical system constructed of only a plurality of reflection optical elements (mirrors), wherein EUV (Extreme Ultra Violet) rays having the oscillation spectrum in, e.g., 5 - 15 nm (soft X-ray region) are used as the exposure illumination light, the illumination area on the reflection mask is defined in the circular-arc slit shape, and the pattern of the reflection mask is transferred onto the wafer by

moving the reflection mask and the wafer in synchronization at the velocity ratio corresponding to the magnification of the reduction projection optical system.

Further, the present invention can be also applied to an electron exposure apparatus and a scan type X-ray exposure apparatus based on a proximity method.

Moreover, the projection optical system PL may be any one of a reduction system, an equal-magnification system and an enlarging system. Further, the projection optical system PL is not limited to the refractive system constructed of the plurality of refraction optical elements but may be either a cata-dioptric system having a refractive optical element and a reflection optical element (such as a concave mirror) or a reflection system constructed of only a plurality of reflection optical elements. Herein, the cata-dioptric type projection optical system may be exemplified by an optical system having at least a concave mirror and a beam splitter as reflection optical elements, an optical system having a concave mirror and a mirror without using the beam splitter as a reflection optical element, and an optical system in which a plurality of refractive optical elements and two pieces of reflection optical elements (at least one element is a concave mirror) are arranged on the same optical axis as disclosed in U.S.P.5,031,976, U.S.P.5,788,229 and U.S.P.5,717,518.

Furthermore, the present invention is applied to an exposure apparatus for transferring a circuit pattern onto a glass substrate or a silicon wafer in order to manufacture the reticle or the mask used for not only the micro device such as the semiconductor device but also the light exposure apparatus, the EUV exposure apparatus, the X-ray exposure apparatus and the electron exposure apparatus. Herein, in the exposure apparatus using DUV (far ultraviolet) rays and VUV (vacuum ultraviolet) rays, a transmission type reticle is generally used, and a reticle substrate involves the use of quartz glass, quartz glass doped with fluorine, fluorite, magnesium fluoride or crystal. Further, in the EUV exposure apparatus involves the use of a reflection type mask. The proximity type X-ray exposure apparatus or the electron exposure apparatus uses a transmission type mask (stencil, membrane mask), and the mask substrate involves the use of the silicon wafer, etc..

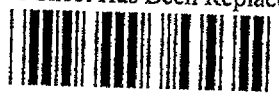
Incidentally, the exposure apparatus in the embodiment discussed above can be manufactured by incorporating the illumination optical system constructed of the plurality of optical elements and the projection optical system into the exposure apparatus body, then making an optical adjustment, composing the wafer holder and the wafer table explained in the embodiment by use of the low expansibility material, attaching the reticle stage and the wafer stage that are

constructed of a multiplicity of machine parts containing the above components to the exposure apparatus body, connecting wires and pipes thereto, and further performing general adjustments (electric adjustment, operational confirmation, etc.). It is noted that it is desirable that the exposure apparatus be manufactured within a clean room where the temperature and a degree of cleanness are controlled.

Moreover, the semiconductor device is manufactured by executing a step of designing a function and performance of the device, a step of manufacturing the reticle based on this designing step, a step of manufacturing the wafer by use of a silicon material, a step of exposing the reticle pattern to the light via the wafer by the exposure apparatus in the embodiment discussed above, a step of assembling the device (including a dicing step, a bonding step and a package step), and an inspection step.

The preset invention has the construction explained above and is therefore able to provide the exposure apparatus capable of preventing the deformation due to the thermal expansions of the substrate table, the substrate holder and the fiducial member even when the irradiation power of the exposure light increases, and of manufacturing the high-quality and high-reliability micro device.

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WHAT IS CLAIMED IS:

1. A substrate retaining apparatus comprising:

a base material involving use of low thermal expansibility ceramic of which a thermal expansion coefficient is 0 - 0.5 ppm at a normal temperature; and

a coating material having a larger hardness than said base material and coated over said base material after effecting surface finishing of said base material in a predetermined configuration.

2. A substrate retaining apparatus comprising:

a base material composed of low thermal expansibility ceramic and having a substrate placing surface; and

a coating material having a difference in thermal expansion coefficient from that of said base material, the difference being equal to 5 ppm or smaller, said coating material being coated over said substrate placing surface after working said substrate placing surface.

3. A substrate retaining apparatus according to claim 1 or 2, wherein the low thermal expansibility ceramic is super precision glass ceramic or cordierite-series ceramic or alumina-series ceramic.

4. A substrate retaining apparatus according to claim 3, wherein the glass ceramic composing said base



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material is a non-cavity inorganic and composed of a mixed body of a crystallizing phase and a glass phase.

5. A substrate retaining apparatus according to any one of claims 1, 3 and 4, wherein a difference in thermal expansion coefficient between said coating material and said base material is within 5 ppm.

6. A substrate retaining apparatus according to claims 1 through 5, wherein said coating material is composed of DLC or TiC or TiN.

7. A substrate retaining apparatus according to claims 1 through 6, wherein a coating thickness is 1 - 10μm.

8. A substrate retaining apparatus according to claim 1, wherein said substrate retaining apparatus is disposed in an exposure apparatus for transferring a pattern of a mask on a photosensitive substrate, and is provided at a stage for relatively moving said photosensitive substrate with respect to said mask.

9. A method of manufacturing a substrate retaining apparatus, comprising:

a step of using, as a base material, low thermal expansibility ceramic of which a thermal expansion

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coefficient is 0 - 0.5 ppm at a normal temperature; and

a step of coating said base material with a material having a larger hardness than said base material after effecting surface finishing of said base material in a predetermined configuration.

10. A method of manufacturing a substrate retaining apparatus, comprising:

a step of working a substrate placing surface of a base material composed of low thermal expansibility ceramic; and

a step of thereafter coating the substrate placing surface with a material of which a difference in thermal expansion coefficient from that of said base material is equal to 5 ppm or smaller.

11. An exposure apparatus comprising:

a substrate table;

a substrate holder disposed on said substrate table;

a fiducial member formed with a fiducial mark and disposed on said substrate table;

an illumination optical system for illuminating a mask with light; and

a projection optical system for projecting an image of a pattern from the mask onto a photosensitive substrate held by said substrate holder,

wherein said substrate table, said substrate holder



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and said fiducial member are composed of low thermal expansibility materials of which thermal expansion coefficients are substantially equal to each other.

12. An exposure apparatus according to claim 11, wherein said substrate table, said substrate holder and said fiducial member are composed of the same material.

13. An exposure apparatus according to claim 11, wherein the low thermal expansibility material is a ceramic material of which a thermal expansion coefficient is equal to 0.5 ppm or smaller.

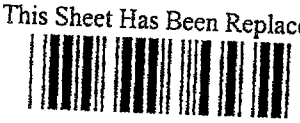
14. An exposure apparatus according to claim 13, wherein the low thermal expansibility material is a ceramic material of which a thermal expansion coefficient is equal to 0.1 ppm or smaller.

15. An exposure apparatus according to claim 13, wherein the low thermal expansibility material is a super precision glass ceramic material or a cordierite-series ceramic material or an alumina-series ceramic material.

16. An exposure apparatus according to claim 14, wherein the glass ceramic material is composed of a mixed body of a crystallizing phase and a glass phase.

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17. An exposure apparatus according to claim 11, wherein a reflection mirror for detecting a position of said substrate table is composed of the same material as that of said substrate table and is provided on said substrate table.

18. An exposure apparatus according to any one of claim 11, wherein said reflection mirror for detecting the position of said substrate table is formed by polishing a part of said substrate table and vapor-depositing a metal exhibiting a high reflectivity.

19. An exposure apparatus according to claim 11, wherein said substrate holder is, after being finished in a predetermined configuration, coated with a material having a hardness larger than that of the low thermal expansibility material.

20. An exposure apparatus according to claim 19, wherein a difference in thermal expansion coefficient between said coating material and said base material is within 5 ppm.

21. An exposure apparatus according to claim 19, wherein said coating material is composed of DLC or TiC or TiN.



22. An exposure apparatus according to claim 19, wherein a coating thickness is 1 - 10μm.

23. A method of manufacturing an exposure apparatus comprising:

a substrate table;

a substrate holder disposed on said substrate table;

a fiducial member formed with a fiducial mark and disposed on said substrate table;

an illumination optical system for illuminating a mask with light; and

a projection optical system for projecting an image of a pattern from the mask onto a photosensitive substrate held by said substrate holder,

said method comprising:

a step of composing said substrate table, said substrate holder and said fiducial member by use of low thermal expansibility materials of which thermal expansion coefficients are substantially equal to each other.

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