

DESCRIPTION

RESIST SENSITIVITY EVALUATION METHOD, TRANSFER MASK MANUFACTURING METHOD, IMPRINT MOLD MANUFACTURING METHOD, RESIST-AFFIXED BASE-MEMBER SUPPLY METHOD, AND RESIST-AFFIXED BASE-MEMBER

Technical Field

[0001] The present invention relates to a resist sensitivity evaluation method, a transfer mask manufacturing method, an imprint mold manufacturing method, a resist-affixed base-member supply method, and a resist-affixed base-member.

Background Art

[0002] Recently, along with developments of finer structures in semiconductor devices, the demands for dimensional precision of resist patterns on mask blanks are becoming increasingly stringent. Transfer patterns are often formed for generations of 32 nm half-pitch generation DRAM or later generations, giving rise to a need to form auxiliary patterns such as sub-resolution assist features (SRAF) with a line width of 40 nm or less, and a high level of dimensional precision is also demanded for the SRAF patterns as well as the main pattern. More specifically, there are demands for critical dimension uniformity (CDU), which is an indicator of in-plane uniformity of a resist pattern, of 5 nm or lower, with 3 nm or lower being preferable.

Similarly, the requirements for dimensional precision have also become more stringent in technology related to imprint molds for forming fine recesses and protrusions using a photolithography method.

In order to accommodate such demands, it must be possible to appropriately evaluate the in-plane distribution of resist sensitivity for resist layers that form the basis of the resist patterns.

[0003] With regard to resist sensitivity of resist layers on mask blanks, for example, there is a proposal in which the resist layer is developed, and the quality of in-plane distribution of resist pattern dimensions obtained as a result is evaluated (see, for example, Patent Document 1). Moreover, there is also another proposal to radiate ultraviolet light onto a resist layer, and to evaluate the sensitivity of the resist layer based on the amount of reflected light (see, for example, Patent Document 2).

Related Documents

Related Patent Documents

[0004] Patent Document 1: Japanese Laid-Open Patent Publication No. 2005-326581

Patent Document 2: Japanese Laid-Open Patent Publication No. 2009-271473

SUMMARY OF INVENTION

Technical Problem

[0005] However, there are the following difficulties with conventional resist sensitivity evaluation methods.

For example, the method disclosed in Patent Document 1 is a destructive test of the resist layer, due to the need to develop the resist layer. Hence it is not possible to perform patterning or the like on the resist layer after testing, and so this method cannot be said to always be appropriate for performing sensitivity evaluation on resist layers.

Moreover, for example, in the method disclosed in Patent Document 2, due to the need to radiate ultraviolet light onto the resist layer, there is a concern regarding a detrimental effect, depending on the type of resist material, on the pattern forming region of the resist layer in cases in which, for example, the entire surface of the resist layer is a region subjected to irradiation by ultraviolet light, and so a sampling test must be performed on portion of the mask blank. Moreover, the in-plane distribution of resist sensitivity in the pattern forming region cannot be ascertained in cases in which regions other than the pattern forming region are regions subject to irradiation by ultraviolet light. Namely, this method cannot be considered to be appropriate for performing sensitivity evaluation on resist layers in either of these cases.

[0006] An object of the present invention is to provide a resist sensitivity evaluation method, a transfer mask manufacturing method, an imprint mold manufacturing method, a resist-affixed base-member supply method, and a resist-affixed base-member that are capable of appropriate evaluation of in-plane distribution of resist sensitivity of resist layers.

Solution to Problem

[0007] Although one factor in the variation in resist sensitivity is discrepancy in the film thickness of the resist layer, other causes are the thermal history imparted to the resist layer, uneven distribution of the resist composition that has arisen when coating the resist material, and the like. In particular, uneven distribution of the resist composition may be a major factor in the variation in resist sensitivity due, for example, to distributions arising in the main polymer molecular weight. Such considerations make it conceivable that evaluation of variation in resist sensitivity in the resist layer can be performed by ascertaining any uneven distribution in the resist composition configuring the resist layer.

The resist composition mainly includes a light sensitive resin, a photo acid generator (PAG), a basic compound, a surfactant, an organic solvent as a solvent, and the like. In such resist compositions, a resist coating film is formed as a resist material by coating onto a base-member, and then a resist layer is formed through heat treatment called pre-exposure

baking (pre-baking) of the resist coating film. When this is performed, the solvent of the resist composition is driven off by the heat treatment. Thus if there is an uneven distribution of the resist composition other than the solvent then the uneven distribution will materialize due to the heat treatment. Namely, when the resist coating film is heat treated to form the resist layer, the resist film thickness decreases due to the heat treatment, and if there is an unevenness in the distribution of resist composition, then this unevenness will materialize due to the heat treatment, causing variation to arise in the resist film reduction ratio according to the unevenness.

This phenomenon conceivably means that there is a correlation between the variation in the resist film reduction ratio in-plane when the resist layer is obtained, and the in-plane resist sensitivity of the resist layer. As a result of thorough investigations by the present inventors, they have made the new discovery that such a correlation does indeed exist.

The present invention is based on the above-described new discovery by the inventors.

[0008] *First Configuration*

A first configuration of the present invention is a resist sensitivity evaluation method including: a process of forming a resist coating film on a surface of a base-member; a process of measuring the film thickness of the resist coating film and generating a first film thickness map; a process of heat treating the resist coating film to give a resist layer; a process of measuring the film thickness of the resist layer and generating a second film thickness map; a process of using the first film thickness map and the second film thickness map to generate a pre-post heat treatment resist film reduction ratio map; and a process of evaluating the resist sensitivity distribution of the resist layer based on the resist film reduction ratio map.

[0009] *Second Configuration*

A second configuration of the present invention is a transfer mask manufacturing method including: a process of forming a resist coating film on a mask blank having a thin film, on the thin film side surface of the mask blank; a process of measuring the film thickness of the resist coating film and generating a first film thickness map; a process of heat treating the resist coating film to give a resist layer; a process of measuring the film thickness of the resist layer and generating a second film thickness map; a process of using the first film thickness map and the second film thickness map to generate a pre-post heat treatment resist film reduction ratio map; and a process of determining an exposure intensity by utilizing the resist film reduction ratio map, or a resist sensitivity distribution map of the resist layer generated based on the resist film reduction ratio map, and performing patterned exposure of the resist layer.

[0010] *Third Configuration*

A third configuration of the present invention is the transfer mask manufacturing method of the second configuration, further including a process of coating a resist material onto the thin film side surface, wherein the process of forming the resist coating film includes crude drying of the resist material to give the resist coating film.

[0011] *Fourth Configuration*

A fourth configuration of the present invention is an imprint mold manufacturing method including: a process of forming a resist coating film on a surface of an imprint mold blank; a process of measuring the film thickness of the resist coating film and generating a first film thickness map; a process of heat treating the resist coating film to give a resist layer; a process of measuring the film thickness of the resist layer and generating a second film thickness map; a process of using the first film thickness map and the second film thickness map to generate a pre-post heat treatment resist film reduction ratio map; and a process of determining an exposure intensity by utilizing the resist film reduction ratio map, or a resist sensitivity distribution map of the resist layer generated based on the resist film reduction ratio map, and performing patterned exposure of the resist layer.

[0012] *Fifth Configuration*

A fifth configuration of the present invention is the imprint mold manufacturing method of the fourth configuration, further including a process of coating a resist material onto the surface, wherein the process of forming the resist coating film includes crude drying of the resist material to give the resist coating film.

[0013] *Sixth Configuration*

A sixth configuration of the present invention is a resist-affixed base-member supply method employed for a resist-affixed base-member obtained by forming a resist coating film on the surface of a base-member then heat treating the resist coating film to give a resist layer, when supplying the resist-affixed base-member, the resist-affixed base-member supply method including: generating a pre-post heat treatment resist film reduction ratio map by employing a first film thickness map obtained by measuring the film thickness of the resist coating film, and a second film thickness map obtained by measuring the film thickness of the resist layer; and supplying the resist-affixed base-member accompanied by at least one out of the resist film reduction ratio map or a resist sensitivity distribution map of the resist layer generated based on the resist film reduction ratio map.

[0014] *Seventh Configuration*

A seventh configuration of the present invention is a resist-affixed base-member obtained by forming a resist coating film on the surface of a base-member then heat treating

the resist coating film to give a resist layer, accompanied by at least one out of a pre-post heat treatment resist film reduction ratio map generated by employing a first film thickness map obtained by measuring the film thickness of the resist coating film and a second film thickness map obtained by measuring the film thickness of the resist layer, or a resist sensitivity distribution map of the resist layer generated based on the resist film reduction ratio map.

Advantageous Effects of Invention

[0015] The present invention enables the in-plane distribution of resist sensitivity in a resist layer to be appropriately evaluated.

BRIEF DESCRIPTION OF DRAWINGS

[0016] Fig. 1 is a schematic diagram illustrating an example of a configuration of a resist-affixed mask blank in an embodiment of the present invention.

Fig. 2 is a flow diagram illustrating an example of a resist sensitivity evaluation procedure in an embodiment of the present invention.

Fig. 3 is an explanatory diagram illustrating a specific example of a resist film reduction ratio map.

Fig. 4 is an explanatory diagram illustrating a specific example of measurement results of resist sensitivity.

DESCRIPTION OF EMBODIMENTS

[0017] Explanation follows regarding embodiments of the present invention, with reference to the drawings.

Explanation of the present embodiments will be split into sections in the following sequence.

1. Transfer Mask
2. Resist-Affixed Mask Blank
3. Resist Sensitivity Evaluation Method
4. Resist-Affixed Mask Blank Supply Method
5. Transfer Mask Manufacturing Method
6. Advantageous Effects of Present Embodiments
7. Modified Examples

[0018] *1. Transfer Mask*

A simple explanation will first be given regarding a transfer mask.

Transfer masks explained in the present embodiment are, for example, employed in semiconductor device fabrication processes, for forming fine patterns on semiconductor substrates.

[0019] Examples of transfer masks include: binary masks that include light-shielding

regions formed by a light-shielding film pattern, and light-transmitting regions that transmit light (semiconductor exposure light); halftone phase shift masks that adjust the light transmissivity of light-shielding regions in a binary mask to an extent that the pattern is not transferred, and invert phase; and Levenson phase shift masks that control phase in light-transmitting regions of a transfer mask.

[0020] Binary masks, halftone phase shift masks, and Levenson phase shift masks, are all manufactured by employing mask blanks. Mask blanks, as described in detail later, have a thin film for forming light-shielding regions (light semi-transmitting regions in the case of Levenson phase shift masks) formed on a base-member made from a light-transmitting substrate. A resist layer is formed on the thin film of the mask blank, and the resist layer is employed when patterning light-shielding films, phase shift films, etc. to form the light-shielding regions and the light-transmitting regions.

[0021] Another example of a transfer mask is an extreme ultraviolet (EUV) mask employed in extreme ultraviolet photolithography. An EUV mask is configured with an absorber pattern formed from a multilayer reflective film and a light-absorbing film on the front surface of low thermal expansion glass, and has absorbing regions where exposure light is absorbed by the absorber pattern, and reflecting regions where the multilayer reflective film is exposed. Such EUV masks are likewise manufactured by employing mask blanks. The resist layer on the mask blank is employed when patterning the light-absorbing film to form the absorbing regions and the reflecting regions.

[0022] 2. Resist-Affixed Mask Blank

Explanation next follows regarding a mask blank employed in manufacturing a transfer mask.

Fig. 1 is a schematic diagram illustrating an example of a configuration of a resist-affixed mask blank in the present embodiment.

[0023] The mask blank 1 of the illustrated example is configured with a thin film 3 formed on one surface of a base-member 2. A resist layer 4 is formed on the surface of the mask blank 1 on the thin film 3 side. In the present embodiment, when the thin film 3 has been formed on the base-member 2, this is referred to as a mask blank 1, and when the resist layer 4 has also been formed, to give a configuration including the base-member 2, the thin film 3, and the resist layer 4, this is referred to as a resist-affixed mask blank 5.

[0024] When employed in a light transmitting transfer mask, the base-member 2 employs a glass substrate that is a light-transmitting substrate. Specifically, the base-member 2 to be employed in any of a binary mask, a halftone phase shift mask, or a Levenson phase shift mask, is selected to have a high transmissivity to the exposure light during mask use.

Therefore, for example, synthetic quartz glass is employed when an ArF excimer laser (wavelength 193 nm) is applied as the exposure light. There are also cases in which soda-lime glass, or the like is employed, depending on the application.

When the base-member 2 is employed in a light reflection-type transfer mask, there is no need for transmissivity to the exposure light during mask use. However, since EUV exposure light has high energy, for example, a wavelength of 13.5 nm, it is conceivable that this energy will cause a rise in temperature of the base-member 2. Thus, due to concerns regarding pattern misalignment arising from the effects of thermal expansion, a low thermal expansion glass is employed as the base-member 2. Specific examples of low thermal expansion glass include SiO₂-TiO₂ glass.

[0025] The thin film 3 employs a metal thin film with light-shielding properties when employed in a light transmitting transfer mask. Specific examples of metal thin films are given below.

When the thin film 3 is employed in a reflection-type transfer mask, a metal thin film with light absorbing properties is employed. Specific examples of metal thin films are given later.

[0026] In cases of both light transmitting transfer masks and reflection-type transfer masks, the resist layer 4 is conceivably formed using a chemically amplified resist material for electron-beam lithography. However, there not necessarily a limitation thereto, and another resist material may be employed as long as pattern forming can be performed by writing and developing using exposure light. The resist layer 4 may be either a positive resist or a negative resist.

[0027] Specific examples of the thus configured mask blank 1 are given in the following (a) to (e).

[0028] (a) Binary mask blanks provided with a light-shielding film formed from a material including a transition metal.

Such binary mask blanks are forms having a thin film that functions as a light-shielding film formed on a base-member made from a light-transmitting substrate. The light-shielding film is made from a material that includes a transition metal, such as chromium, tantalum, ruthenium, tungsten, titanium, hafnium, molybdenum, nickel, vanadium, zirconium, niobium, palladium, or rhodium, or includes a compound thereof. Examples of light-shielding films include those configured from a chromium compound including chromium, and one or more elements selected from oxygen, nitrogen, carbon, etc. added to chromium. Examples also include a light-shielding film configured from a tantalum compound with one or more elements selected from oxygen, nitrogen, boron, etc. added to

tantalum.

Such binary mask blanks include those with a light-shielding film of a two layer structure including a light-shielding layer and a front face anti-reflection layer, and those with a light-shielding film of a three layer structure with an additional rear face anti-reflection layer between a light-shielding layer and the substrate.

The composition of the light-shielding film may be that of a compositionally graded film that differs in composition either continuously or stepwise in the film thickness direction. [0029] (b) Phase shift mask blanks provided with a light semi-transmitting film made from a material including a compound of a transition metal and silicon (including transition metal silicides, and in particular molybdenum silicide).

Such phase shift mask blanks include forms having a thin film that functions as a light semi-transmitting film formed on a base-member made from a light-transmitting substrate (glass substrate), and mask blanks for halftone phase shift masks of a type provided with a shifter portion by patterning the light semi-transmitting film. In such phase shift masks, since pattern defects in the substrate transferred onto are prevented by the light semi-transmitting film pattern formed in the transfer regions based on the light transmitted through the light semi-transmitting film, a form of mask is preferable that includes a light semi-transmitting film formed on a transmitting substrate and a light-shielding film (light-shielding band) thereon. In addition to halftone phase shift mask blanks, examples also include mask blanks employed in Levenson phase shift masks and enhancer-type phase shift masks that have an engraved-type substrate provided with a shifter engraved into a transmitting substrate by etching or the like.

[0030] The light semi-transmitting film in such halftone phase shift mask blanks is one that transmits light of an intensity that makes substantially no contribution to exposure (for example, 1% to 30% at the exposure light wavelength), and induces a specific phase difference (for example 180 degrees). Due to the light semi-transmitting film being patterned into light semi-transmitting portions, and light transmitting portions that are not formed with a light semi-transmitting film and that transmit light at an intensity that makes substantially no contribution to exposure, the phase of the light that has been transmitted by the light semi-transmitting portions and the phase of the light transmitted through the light transmitting portions have a substantially inverted relationship to each other, such that light passing through the vicinity of a boundary portion between the light semi-transmitting portions and the light transmitting portions that infiltrates into each other's regions due to diffraction effects cancel each other out, and the light intensity at the boundary portion is substantially zero, raising the contrast (namely the resolution) of the boundary portion.

[0031] The light semi-transmitting film is, for example, made from a material including a compound of a transition metal and silicon (including transition metal silicides), and examples thereof include a material with main constituent elements of a transition metal and silicon, and oxygen and/or nitrogen. The transition metal may be molybdenum, tantalum, tungsten, titanium, hafnium, nickel, vanadium, zirconium, niobium, palladium, ruthenium, rhodium, chromium, or the like.

In a form in which there is a light-shielding film on a light semi-transmitting film, due to the material of the light semi-transmitting film including a transition metal and silicon, the material of the light-shielding film preferably has etching selectivity (has etching resistance) with respect to the light semi-transmitting film, and is particularly preferably configured from a chromium compound including chromium, and one element selected from oxygen, nitrogen, carbon, or the like added to chromium.

[0032] Since a Levenson phase shift mask is manufactured from a mask blank configured similarly to that of a binary mask blank, the configuration of the pattern forming thin film is similar to the light-shielding film of a binary mask blank. The light semi-transmitting film of a mask blank employed in an enhancer-type phase shift mask is one that transmits light of an intensity that makes substantially no contribution to exposure (for example, 1% to 30% at the exposure light wavelength), and is a film that induces a small phase difference in the transmitted exposure light (for example, a phase difference of 30 degrees or less, and preferably 0 degrees), and in this respect differs from the light semi-transmitting film of a halftone phase shift mask blank. The material of the light semi-transmitting film includes similar elements to those of the light semi-transmitting film of the halftone phase shift mask blank, however the composition ratio of each element and the film thickness are adjusted to give a specific transmissivity to exposure light, and a specific small phase difference.

[0033] (c) A binary mask blank provided with a light-shielding film made from a material including a transition metal, or a compound of a transition metal and silicon (including transition metal silicides, and in particular molybdenum silicide).

Such light-shielding films are made from materials including a compound of a transition metal and silicon, and examples include materials with main configuration elements of the transition metal and silicon, and oxygen and/or nitrogen. Examples of the light-shielding film include materials with main configuration elements of a transition metal, and oxygen, nitrogen, and/or boron. The transition metal may be molybdenum, tantalum, tungsten, titanium, hafnium, nickel, vanadium, zirconium, niobium, palladium, ruthenium, rhodium, chromium, or the like.

In particular, there are cases in which the light-shielding layer is formed with a

compound of molybdenum silicide in a two layer structure of a light-shielding layer (MoSi or the like) and a front face anti-reflection layer (MoSiON or the like), or a three layer structure further including a rear face anti-reflection layer (MoSiON or the like) between the light-shielding layer and the substrate.

The light-shielding film may be a compositionally graded film that differs in composition either continuously or stepwise in the film thickness direction of the light-shielding film.

[0034] In order to make the film thickness of the resist layer thinner and to form a fine pattern, an etching mask film may be formed on the light-shielding film. Such an etching mask film is preferably has etching selectivity (has etching resistance) with respect to etching of the light light-shielding film including the transition metal silicide, and is particularly preferably configured from a material made from a chromium compound including chromium, and an element such as oxygen, nitrogen, or carbon added to chromium. In such cases a transfer mask may be manufactured in a state in which the etching mask film remains on the light-shielding film by imparting the etching mask film with anti-reflection properties.

[0035] (d) Multi-gradation mask blank provided with a stacked layer structure of one or more semi-transmitting film and a light-shielding film.

Materials for the semi-transmitting film include materials including a compound of similar elements to the light semi-transmitting film of the halftone phase shift mask blanks described above, and include metals such as chromium, tantalum, titanium, or aluminum, singly or in an alloy thereof. The composition ratio of each element and the film thickness are adjusted to give a specific transmissivity to exposure light. The material of the light-shielding film may also be applied as the material of the light-shielding film of the binary mask blanks described above, however in a stacked layer structure with the semi-transmitting film, the composition and the film thickness of the light-shielding film material is adjusted to give a specific light-shielding performance (optical density).

[0036] Moreover, in (a) to (d) above, an etching stopper film having etching resistance with respect to the light-shielding film and the light semi-transmitting film may be provided between the light-transmitting substrate (glass substrate) and the light-shielding film, or between the light semi-transmitting film and the light-shielding film. The etching stopper film may be a material that enables the etching mask film to be simultaneously removed when the etching stopper film is etched.

[0037] (e) Reflection-type mask blank provided with an absorber film on a multilayer reflecting film formed with alternately stacked high refractive index layers and low refractive index layers.

Reflection-type masks are masks employed in EUV lithography. A reflection-type mask has a structure in which a multilayer reflecting film that reflects exposure light is formed on a substrate, and an absorber film that absorbs exposure light is formed in a pattern on the multilayer reflecting film. Light (EUV light) incident to the reflection-type mask mounted in an exposure machine (pattern transfer apparatus) is absorbed at portions where the absorber film is present, and an image of light reflected by the multilayer reflecting film at portions where there is no absorber film is transferred onto a semiconductor substrate through an optical reflection system.

[0038] The multilayer reflecting film is formed by alternately stacked layers of high refractive index layers and low refractive index layers. Examples of the multilayer reflecting film include a Mo/Si periodic multilayer film of approximately 40 periods of layers of alternating Mo films and Si films, a Ru/Si periodic multilayer film, a Mo/Be periodic multilayer film, a Mo compound/Si compound periodic multilayer film, a Si/Nb periodic multilayer film, a Si/Mo/Ru periodic multilayer film, a Si/Mo/Ru/Mo periodic multilayer film, a Si/Ru/Mo/Ru periodic multilayer film, and the like. This material may be appropriately selected according to the exposure light wavelength.

[0039] The absorber film has the function of absorbing exposure light, for example EUV light, and preferably employs, for example, tantalum (Ta) singly, or a material including Ta as a main component. The crystallinity of such an absorber film preferably has an amorphous form, or a microcrystalline structure from the perspectives of smoothness and flatness.

[0040] Examples of materials including Ta as a main component that may be employed include a material including Ta and B, a material including Ta and N, a material including Ta and B as well as at least one out of O and N, a material including Ta and Si, a material including Ta, Si, and N, a material including Ta and Ge, a material including Ta, Ge and N, a material including Ta and Hf, a material including Ta, Hf, and N, a material including Ta and Zr, a material including Ta, Zr, and N, and the like. Adding B, Si, Ge or the like to Ta enables an amorphous material to be easily obtained, enabling the smoothness to be raised. Adding N and/or O to Ta raises the resistance to oxidation, thereby obtaining the advantageous effect of enabling the stability over time to be raised.

[0041] 3. *Resist Sensitivity Evaluation Method*

Explanation next follows regarding a procedure for resist sensitivity evaluation for the resist layer 4 of the resist-affixed mask blank 5. Explanation here of the procedure for resist sensitivity evaluation includes the procedure for forming the resist layer 4.

Fig. 2 is a flow diagram illustrating an example of a procedure for resist sensitivity evaluation in the present embodiment.

[0042] *Coating Process: S11*

The resist layer 4 to be subject to evaluation needs to be formed in order to evaluate the resist sensitivity of the resist layer 4. Thus in a coating process (S11), a resist material that is the material for forming the resist layer 4 is coated onto the upper side of one face of the base-member 2, or more specifically, onto the thin film side surface face of a mask blank 1 configured with the thin film 3 on the face of the base-member 2.

[0043] The resist material is configured by plural types of resist composition. One example of a resist composition mainly includes a light sensitive resin, a photo acid generator (PAG), a basic compound, a surfactant, an organic solvent as a solvent, and the like. In such resist compositions, at least the light sensitive resin is distributed as a colloid in the solvent.

[0044] Examples of methods of coating a resist material made from such a resist composition onto the surface of the mask blank 1 include a spin coating method. A spin coating method gives excellent film thickness uniformity when coating the resist material. However, when the resist material is being spread over the surface of the mask blank 1, centrifugal force acts on the resist composition configuring the resist material, and so even though there appears to be excellent film thickness uniformity, each component of the resist composition may be unevenly distributed due to centrifugal separation.

[0045] *Crude Drying Process: S12*

After the coating process (S11) has been completed, as a crude drying process (S12), the resist material coated onto the surface of the mask blank 1 is crudely dried. A resist coating film is thereby formed on the surface of the mask blank 1.

[0046] *First Measurement Process: S13*

After performing the crude drying process (S12) to form the resist coating film, then, as a first measurement process (S13), the film thickness of the formed resist coating film is measured, and a first film thickness map is generated.

[0047] The film thickness measurement is performed on the resist coating film over an entire in-plane region of the resist coating film. However, plural locations may be sampled from out of the entire in-plane region, and film thickness measurement may be performed for the sampled points. The method of film thickness measurement may be any non-destructive, non-contact method, and may conceivably be performed by known methods such as a spectral interference method, a phase-sensitive eddy current method, a magnetic induction method, or X-ray fluorescence.

[0048] The first film thickness map expresses film thickness measurement results over the entire in-plane region of the resist coating film on a two dimensional coordinate flat plane corresponding to the in-plane region.

[0049] *Heat Treatment Process: S14*

After the first film thickness map has been generated in the first measurement process (S13), then as a heat treatment process (S14), heat treatment called pre-exposure bake (pre-bake) is performed on a resist coating film on the surface of the mask blank 1. The temperature and time of the heat treatment may be predetermined according to the type of resist material that is the basis of the resist coating film. The resist layer 4 is formed on the surface of the mask blank 1 through performing the heat treatment (pre-bake).

[0050] When this is being performed, the solvent of the resist composition configuring the resist coating film is driven off by the heat treatment. Thus if there is an uneven distribution of the resist composition other than the solvent then the uneven distribution will materialize due to the heat treatment. Namely, when the resist coating film is heat treated to form the resist layer 4, the resist film thickness decreases due to the heat treatment, and if there is an unevenness in the distribution of resist composition, then this unevenness will materialize due to the heat treatment, causing variation to arise in the resist film reduction ratio according to the unevenness.

[0051] *Second Measurement Process: S15*

When the resist layer 4 has been formed by performing the heat treatment process (S14), the film thickness of the formed resist layer 4 is measured in the second measurement process (S15), and a second film thickness map generated.

[0052] The film thickness measurement of the resist layer 4 is performed over the entire in-plane region of the resist layer 4, similarly to in the first measurement process (S13) described above. However, plural locations may be sampled from out of the entire in-plane region, and film thickness measurement may be performed for the sampled points. In such cases, the sampled locations correspond to the locations sampled in the first measurement process (S13). The method of film thickness measurement may be any non-destructive, non-contact method, and may conceivably be performed by known methods such as a spectral interference method, a phase-sensitive eddy current method, a magnetic induction method, or X-ray fluorescence.

[0053] The second film thickness map expresses film thickness measurement results over the entire in-plane region of the resist layer 4 on a two dimensional coordinate flat plane corresponding to the in-plane region.

[0054] *Map Generation Process: S16*

After the second film thickness map has been generated by the second measurement process (S15), then, in combination with the first film thickness map obtained by the first measurement process (S13), film thickness measurement results are complete for both before

and after the heat treatment. Thus after the second measurement process (S15), as a map generation process (S16), the first film thickness map and the second film thickness map are employed to generate a pre-post heat treatment resist film reduction ratio map.

[0055] The resist film reduction ratio map expresses calculated results of the resist film reduction ratio for the entire in-plane region of the resist layer 4 on a two dimensional coordinate flat plane corresponding to the in-plane region. The resist film reduction ratio is the reduction in film amount of the film thickness of the resist layer 4 after heat treatment from the film thickness of the resist coating film before heat treatment, calculated as a proportion of the film thickness of the resist coating film.

[0056] *Evaluation Process: S17*

After the resist film reduction ratio map has been generated in the map generation process (S16), an evaluation process (S17) is performed if required (for example, at a point in time prior to performing exposure of the resist layer 4 for patterning). In the evaluation process (S17), the resist sensitivity distribution of the resist layer 4 is evaluated based on the resist film reduction ratio map.

[0057] The resist sensitivity distribution may conceivably be evaluated in the following manner.

[0058] After the map generation process (S16) has been completed, the resist film reduction ratio map is obtained for the resist layer 4 that is subject to evaluation. The resist film reduction ratio map expresses the resist film reduction ratio for the entire in-plane region of the resist layer 4 on a two dimensional coordinate flat plane. Thus the distribution state of variation in the in-plane resist film reduction ratio of the resist layer 4 can be ascertained from the resist film reduction ratio map. The variation in resist film reduction ratio may be understood as being the unevenness in the resist composition that is the base configuring the resist layer 4, materialized due to the heat treatment. The unevenness in the resist compositions may be a major factor in variation in resist sensitivity. In consideration thereof, there can be said to be a correlation between variation in resist film reduction ratio and variation in resist sensitivity.

[0059] The relationship between the variation in resist film reduction ratio and variation in resist sensitivity conceivably depends on the type of resist material. Namely, if the type of resist material is identified, the correlation between the resist film reduction ratio and the resist sensitivity can be identified at the same time, enabling the resist sensitivity to be uniquely inferred from the resist film reduction ratio as a result.

[0060] In the light of the above, in the evaluation of the resist sensitivity distribution, the resist film reduction ratio is recognized at respective in-plane locations of the resist layer 4

based on the resist film reduction ratio map. Then, based on the correlation between the resist film reduction ratio identified from the type of resist material and the resist sensitivity, a resist sensitivity is uniquely inferred for the respective locations from the resist film reduction ratio of the respective locations on the resist film reduction ratio map, and the in-plane resist sensitivity of the resist layer 4 is evaluated by comparing the inferred result to a pre-set standard sensitivity or permissible sensitivity range.

[0061] The resist sensitivity of the resist layer 4 on the resist-affixed mask blank 5 is evaluated through performing the procedure explained above.

[0062] *4. Resist-Affixed Mask Blank Supply Method*

Explanation next follows regarding a supply method for the resist-affixed mask blank 5. The supply method to be explained for the present embodiment is a method employed when the resist-affixed mask blank 5 is supplied to the user side from the manufacturing side of the resist-affixed mask blank 5. The resist-affixed mask blank 5 to be supplied is obtained by heat treating the resist coating film to produce the resist layer 4, after the resist coating film has been formed on the surface of the base-member 2. Reference here to "on the surface of the base-member 2" includes cases on an interposed thin film 3, namely on the thin film 3 side surface of the mask blank 1. Thus the resist-affixed mask blank 5 corresponds to a specific example of a "resist-affixed base-member" of the present invention.

[0063] In supplying the thus configured resist-affixed mask blank 5, a first film thickness map and a second film thickness map generated for the resist layer 4 of the resist-affixed mask blank 5 using similar methods to those described in *3. Resist Sensitivity Evaluation Method* are employed to generate a pre-post heat treatment resist film reduction ratio map. Moreover, in combination with generating the resist film reduction ratio map, a resist sensitivity distribution map for the resist layer 4 is also generated based on the resist film reduction ratio map if required. The resist sensitivity distribution map is uniquely generated from the content of the resist film reduction ratio map, and expresses the distribution state of the resist sensitivity over the entire in-plane region of the resist layer 4 on a two dimensional coordinate flat plane corresponding to the in-plane region.

[0064] Then, when supplying the resist-affixed mask blank 5, at least one out of the resist film reduction ratio map for the resist layer 4 of the resist-affixed mask blank 5, or the resist sensitivity distribution map of the resist layer, is supplied accompanying the resist-affixed mask blank 5. Namely, at least one out of the resist film reduction ratio map or the resist sensitivity distribution map of the resist layer accompanies the resist-affixed mask blank 5 being supplied to the user side.

[0065] By supplying the resist-affixed mask blank 5 in this manner, the user side supplied

with the resist-affixed mask blank 5 is able to reference the accompanying resist film reduction ratio map or resist sensitivity distribution map of the resist layer, and thereby evaluate resist sensitivity distribution for the resist layer 4 of the resist-affixed mask blank 5, using similar methods to those described in 3. *Resist Sensitivity Evaluation Method*.

[0066] 5. *Transfer Mask Manufacturing Method*

Explanation next follows regarding a transfer mask manufacturing method performed employing the resist-affixed mask blank 5.

[0067] The resist layer 4 of the resist-affixed mask blank 5 is employed to pattern a light-shielding film, phase shift film, or the like to form light-shielding regions and light-transmitting regions when the transfer mask to be manufactured is a binary mask, a halftone phase shift mask, or a Levenson phase shift mask. When the transfer mask to be manufactured is an EUV mask, a light absorbing film is patterned to form the absorbing regions and the reflecting regions. In all of these cases, a pattern is written onto the resist layer 4 by exposure to an electron beam, and a resist pattern is produced by performing further development processing.

[0068] The resist pattern at this stage places stringent demands on dimensional precision, such as a CDU that is 5 nm or less, and that is preferably 3 nm or less. In order to conform to such demands, there is a need to obtain an appropriate evaluation of the in-plane distribution of the resist sensitivity of the resist layer 4.

[0069] Regarding this point, the resist film reduction ratio map for the resist layer 4 of the resist-affixed mask blank 5 is generated according to the transfer mask manufacturing method of the present embodiment, and so the in-plane distribution of the resist sensitivity of the resist layer 4 can be appropriately evaluated by utilizing the resist film reduction ratio map, or the resist sensitivity distribution map of the resist layer 4 generated based on the resist film reduction ratio map. Conformation to stringent demands for dimensional precision of the resist pattern is accordingly implementable.

[0070] Specifically, the resist film reduction ratio map, or the resist sensitivity distribution map of the resist layer 4 is utilized when the resist layer 4 is patterned to form the resist pattern, and the exposure intensity for each location in-plane of the resist layer 4 is determined after ascertaining the in-plane distribution of the resist sensitivity of the resist layer 4. Then patterned exposure is performed on the resist layer 4 at the determined exposure intensity. This thereby enables patterned exposure to be performed for each location at the exposure intensity corresponding to the resist sensitivity at the respective in-plane locations of the resist layer 4. Thus, for example, even under stringent demands, such as for a CDU that is 5 nm or less, and that is preferably of 3 nm or less, it is still possible

to form a resist pattern with dimensional precision that meets these demands.

[0071] *6. Advantageous Effects of Present Embodiment*

The present embodiment obtains the following advantageous effects.

[0072] In the present embodiment, the pre-post heat treatment resist film reduction ratio map is generated by employing the first film thickness map obtained by measuring the film thickness of the resist coating film, and the second film thickness map obtained by measuring the film thickness of the resist layer 4, and the resist sensitivity distribution of the resist layer 4 is evaluated based on this resist film reduction ratio map. Namely, in the present embodiment, based on the new discovery by the inventors of the present invention that there is a correlation between the resist film reduction ratio in the resist layer 4 and the resist sensitivity, the resist sensitivity is inferred from the resist film reduction ratio, and the resist sensitivity of the in-plane of the resist layer 4 is evaluated after ascertaining the pre-post heat treatment (pre-bake) resist film reduction ratio of the resist layer 4.

Thus the present embodiment enables the resist sensitivity of the resist layer 4 to be evaluated without needing to develop, or radiate an ultraviolet light beam onto, the resist layer 4. It is sufficient to ascertain the resist film reduction ratio based on the film thickness measurement results, enabling sensitivity evaluation to be performed over the entire in-plane region of the resist layer 4 (including the pattern forming region). Namely, the present embodiment enables appropriate evaluation of in-plane distribution of resist sensitivity of the resist layer 4 to be performed in a short period of time.

[0073] In the present embodiment, the resist film reduction ratio map for the resist layer 4 or the resist sensitivity distribution map generated from the resist film reduction ratio map is utilized, and the exposure intensity is determined for respective in-plane locations of the resist layer 4 after ascertaining the in-plane distribution of the resist sensitivity of the resist layer 4. A resist pattern is then formed by performing patterned exposure of the resist layer 4 at the determined exposure intensity, and the transfer mask is manufactured by employing the resist pattern. Namely, the in-plane distribution of the resist sensitivity of the resist layer 4 is appropriately evaluated, and resist pattern forming can be performed under conditions that take into consideration the evaluation result.

Thus according to the present embodiment, even in cases in which there are stringent demands, such as for a CDU that is 5 nm or less, and that is preferably of 3 nm or less, it is still possible to form a resist pattern with dimensional precision that meets these demands, and as a result the present embodiment is also suitably applied even with the developments in finer structures in semiconductor devices.

[0074] In particular, as explained in the present embodiment, performing a spin coating

method, for coating with the resist material when the resist layer 4 is formed through the coating process (S11) of coating the resist material onto the thin film side surface of the mask blank 1, makes it likely for unevenness to occur in the resist compositions configuring the resist material. However, even in such cases, as explained for the present embodiment, evaluating the in-plane resist sensitivity of the resist layer 4 by employing the pre-post heat treatment resist film reduction ratio of the resist layer 4 causes the unevenness state of the resist compositions to be reflected in the evaluation result. Namely, in the present embodiment, even in cases in which the resist layer 4 is formed under conditions in which unevenness in resist compositions are liable to occur, an appropriate evaluation of in-plane distribution of the resist sensitivity of the resist layer 4 can be achieved.

[0075] In the present embodiment, when the resist-affixed mask blank 5 is supplied, the resist-affixed mask blank 5 is supplied accompanied by at least one out of the resist film reduction ratio map for the resist layer 4 of the resist-affixed mask blank 5, or the resist sensitivity distribution map of the resist layer. Namely, at least one out of the resist film reduction ratio map or the resist sensitivity distribution map of the resist layer accompanies the supplied resist-affixed mask blank 5.

Thus according to the present embodiment, the user side supplied with the resist-affixed mask blank 5 is able to reference the accompanying resist film reduction ratio map or resist sensitivity distribution map of the resist layer, and thereby appropriately evaluate the in-plane distribution of resist sensitivity for the resist layer 4 of the resist-affixed mask blank 5. Namely, from the user side there is extremely high convenience, and by appropriately evaluating the in-plane distribution of the resist sensitivity of the resist layer 4 by employing the accompanying resist film reduction ratio map etc., suitable application can be made even to increasingly high precision resist patterns, finer structures of semiconductor devices, and the like.

[0076] 7. *Modified Examples etc.*

Although an embodiment of the present invention has been explained above, the contents disclosed above are merely an exemplary embodiment of the present invention. Namely, the technical scope of the present invention is not limited to the above exemplary embodiment.

[0077] For example, in the above embodiment, an example has been given of a case in which the present invention is applied to resist evaluation of the resist-affixed mask blank 5, which is employed to manufacture a transfer mask, however, the present invention is not limited thereto, and it is also possible to apply the present invention to resist evaluation of a resist-affixed imprint mold blank employed in manufacturing an imprint mold.

[0078] An imprint mold is employed in pattern transfer by being directly pressed into a resist layer coated onto a transfer target object. Thus the shape, dimensional precision, and the like of fine patterns formed on the surface of the imprint mold has a large influence on the shape, dimensional precision, and the like of the transferred pattern.

[0079] Such an imprint mold is manufactured by employing an imprint mold blank. An imprint mold blank is configured by forming, if required, a chromium based thin film, tantalum based thin film, or the like on a surface of a base-member, such as synthetic quartz glass or the like, and by then forming a resist layer on the surface thereof. Patterning is then performed on a resist layer imprint mold blank using a lithographic method on the resist layer, and an engraved shape is formed on the imprint mold by etching using the resist pattern as a mask, and etching the lower thin film and base-member.

[0080] The present invention is also applicable to resist evaluation of such a resist layer applied imprint mold blank, in exactly the same manner as in the embodiment described above, thereby enabling the in-plane distribution of the resist sensitivity of the resist layer to be evaluated appropriately. In such cases, the resist-affixed imprint mold blank corresponds to a specific example of a "resist-affixed base-member" of the present invention.

[0081] Moreover, as described in the above embodiment, the in-plane resist sensitivity of the resist layer 4 is evaluated by employing the pre-post heat treatment resist film reduction ratio of the resist layer 4. Reference here to after the heat treatment envisages the point in time when the heat treatment has been completed and the resist layer 4 formed, namely a timing immediately after completion of the heat treatment. However, the present invention is not necessarily limited thereto, and the resist film reduction ratio may be found by performing the film thickness measurement at a timing when a specific duration has elapsed since the heat treatment was completed. For example, in cases in which the resist sensitivity varies with the passage of time, evaluation that reflects time-wise variation in resist sensitivity can be performed by using a timing when a specific duration has elapsed since the heat treatment was completed. Film thickness measurement to find resist film reduction ratios may also be conceivably obtained at plural timings after the heat treatment, and such cases enable the time-wise variation in resist sensitivity to be ascertained from the resist film reduction ratio at the respective timings.

Example

[0082] Detailed explanation of the present invention follows regarding an example of a mask blank for manufacturing a halftone phase shift mask. However, the present invention is obviously not limited to the following example.

[0083] In the present example a mask blank was configured as described below. A

synthetic quartz glass substrate was employed as the base-member. As a thin film, a light semi-transmitting film of a MoSiN film having a film thickness of 69 nm, a transmissivity of 6.04% to light of wavelength $\lambda = 193$ nm, and a phase difference of 179.5° was employed. Stacked films of a chromium-lean CrOCN film having a film thickness of 30 nm, and a chromium-rich CrOCN film having a film thickness of 14 nm, were employed as light-shielding films serving as other thin films. The optical density of the light semi-transmitting film and the light-shielding film to light of wavelength $\lambda = 193$ nm was 3.0. [0084] The resist layer was formed as described below. First, as pre-processing, the light-shielding film was treated with HMDS (an adhesion enhancing coating agent) under specific conditions. A chemically amplified positive resist for electron beam writing (PRL009, manufactured by Fujifilm Electronic Materials) was employed as the resist material, a resist coating film formed using a spin coating method as the coating method, so as to give a set film thickness of 120 nm, and the resist coating film was then heat treated (pre-baked), and a resist layer formed.

[0085] Film thickness measurement results before and after heat treatment were employed to generate a resist film reduction ratio map for the resist-affixed mask blank obtained in this manner.

Fig. 3 is an explanatory diagram illustrating a specific example of a resist film reduction ratio map.

In the resist film reduction ratio map in the illustrated example, the entire in-plane region of the resist layer is divided plural times, and the resist film reduction ratio of the respective divided regions is expressed by two dimensional coordinates on a flat plane corresponding to in-plane in the resist layer. Plural values indicated in each of the divided regions are values of the resist film reduction ratio, and are calculated, for example, using the computational equation (pre-post heat treatment film thickness difference/ pre-heat treatment film thickness) $\times 100$. On the resist film reduction ratio map, unlike display brightnesses are imparted to each of the divided regions corresponding to discrepancies in resist film reduction ratio values.

Such a resist film reduction ratio map enables the distribution state of the resist film reduction ratio in the entire in-plane region of the resist layer to be easily ascertained, and enables a unique resist sensitivity to be inferred for the entire in-plane region of the resist layer from the result.

[0086] In order to verify this, the resist sensitivity was actually measured for the resist layer of the resist film reduction ratio map of Fig. 3.

Fig. 4 is an explanatory diagram illustrating a specific example of measurement

results of resist sensitivity.

The measurement results of resist sensitivity in the illustrated example were obtained by measuring critical dimensions (CDs) of the entire in-plane region of the resist layer, and are also sometimes referred to as a CDU map.

[0087] It is apparent from a comparison of the resist film reduction ratio map of Fig. 3 with the CDU map of Fig. 4 that locations with higher resist film reduction ratios in the resist film reduction ratio map have lower sensitivities in a DOSE map. Namely, a clear correlation is shown to be present between the resist film reduction ratio and the resist sensitivity in the in-plane of the resist layer.

Explanation of the Reference Numerals

[0088] 1 mask blank; 2 base-member; 3 thin film; 4 resist layer; 5 resist-affixed mask blank.

CLAIMS

1. A resist sensitivity evaluation method comprising:
 - a process of forming a resist coating film on a surface of a base-member;
 - a process of measuring the film thickness of the resist coating film and generating a first film thickness map;
 - a process of heat treating the resist coating film to give a resist layer;
 - a process of measuring the film thickness of the resist layer and generating a second film thickness map;
 - a process of using the first film thickness map and the second film thickness map to generate a pre-post heat treatment resist film reduction ratio map; and
 - a process of evaluating the resist sensitivity distribution of the resist layer based on the resist film reduction ratio map.
2. A transfer mask manufacturing method comprising:
 - a process of forming a resist coating film on a mask blank having a thin film, on the thin film side surface of the mask blank;
 - a process of measuring the film thickness of the resist coating film and generating a first film thickness map;
 - a process of heat treating the resist coating film to give a resist layer;
 - a process of measuring the film thickness of the resist layer and generating a second film thickness map;
 - a process of using the first film thickness map and the second film thickness map to generate a pre-post heat treatment resist film reduction ratio map; and
 - a process of determining an exposure intensity by utilizing the resist film reduction ratio map, or a resist sensitivity distribution map of the resist layer generated based on the resist film reduction ratio map, and performing patterned exposure of the resist layer.
3. The transfer mask manufacturing method of claim 2, further comprising:
 - a process of coating a resist material onto the thin film side surface, wherein the process of forming the resist coating film includes crude drying of the resist material to give the resist coating film.
4. An imprint mold manufacturing method comprising:
 - a process of forming a resist coating film on a surface of an imprint mold blank;

a process of measuring the film thickness of the resist coating film and generating a first film thickness map;

a process of heat treating the resist coating film to give a resist layer;

a process of measuring the film thickness of the resist layer and generating a second film thickness map;

a process of using the first film thickness map and the second film thickness map to generate a pre-post heat treatment resist film reduction ratio map; and

a process of determining an exposure intensity by utilizing the resist film reduction ratio map, or a resist sensitivity distribution map of the resist layer generated based on the resist film reduction ratio map, and performing patterned exposure of the resist layer.

5. The imprint mold manufacturing method of claim 4, further comprising:

a process of coating a resist material onto the surface, wherein

the process of forming the resist coating film includes crude drying of the resist material to give the resist coating film.

6. A resist-affixed base-member supply method employed for a resist-affixed base-member obtained by forming a resist coating film on the surface of a base-member then heat treating the resist coating film to give a resist layer, when supplying the resist-affixed base-member, the resist-affixed base-member supply method comprising:

generating a pre-post heat treatment resist film reduction ratio map by employing a first film thickness map obtained by measuring the film thickness of the resist coating film, and a second film thickness map obtained by measuring the film thickness of the resist layer; and

supplying the resist-affixed base-member accompanied by at least one out of the resist film reduction ratio map or a resist sensitivity distribution map of the resist layer generated based on the resist film reduction ratio map.

7. A resist-affixed base-member obtained by forming a resist coating film on the surface of a base-member then heat treating the resist coating film to give a resist layer, accompanied by

at least one out of a pre-post heat treatment resist film reduction ratio map generated by employing a first film thickness map obtained by measuring the film thickness of the resist coating film and a second film thickness map obtained by measuring the film thickness of the resist layer, or a resist sensitivity distribution map of the resist layer generated based on the resist film reduction ratio map.