

PROJECTION EXPOSURE METHOD, AND
PROJECTION EXPOSURE APPARATUS AND MASK THEREFOR

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Background of the Invention

The present invention relates to a projection exposure method, and a projection exposure apparatus and a mask therefor and, in particular, to a projection exposure method employing a modified illumination method used for a lithographic process of a semiconductor device, and a projection exposure apparatus and a mask therefor.

For fabrication of ULSI chips having an integration level of 64Mb bits and beyond, a resolution of $0.3\mu\text{m}$ and an adequate depth-of-focus (DOF) are required. Accordingly, many new techniques for making sub-half-micron patterns are under development, including a method using an excimer laser wherein a short wavelength of light is used, an exposure method using a phase shift mask, and a modified illumination method such as a tilted illumination method.

It is known that the resolution (R) and the depth-of-focus (DOF) of the optical projection exposure are proportional to the exposure wavelength (λ) and inversely proportional to the numerical aperture (NA) of a lens, based on Rayleigh's equation which is expressed as

$$R = k_1 \left(\frac{\lambda}{NA} \right)$$
$$DOF = k_2 \left(\frac{\lambda}{NA^2} \right)$$

wherein k_1 and k_2 are generally known to be 0.5-0.8 as process

factors, i.e., coherence factors expressed in terms of σ , obtained by dividing NA_c of an illumination system lens by NA_o of a projection optical system lens. When a coherence factor is not zero, the values of k_1 and k_2 cannot be determined precisely since resolution is largely affected by process capability.

In fabrication of a pattern having a size below $0.3\mu\text{m}$ using a current exposure method, a depth-of-focus larger than $1.6\mu\text{m}$ is necessary, due to a large step height on a processed wafer as well as other errors.

When exposure is performed by using an i-line in a current stepper, the resolution and depth-of-focus are $0.47\mu\text{m}$ and $1.46\mu\text{m}$, respectively, with a wavelength of $0.365\mu\text{m}$, a k_1 of 0.56 and a k_2 of 1.0 given.

In order to obtain a higher resolution, the numerical aperture should be larger or the wavelength should be shorter. When using a conventional KrF excimer laser stepper with a numerical aperture of 0.54 and a wavelength of $0.248\mu\text{m}$, resolution is $0.3\mu\text{m}$ and the depth-of-focus is $0.85\mu\text{m}$. This implies that the current exposure method is not adequate for production of patterns below $0.3\mu\text{m}$, even though a KrF excimer laser is employed.

Additionally, a method utilizing a phase shift mask exhibits the limitation that it is difficult and expensive to manufacture the phase shift mask.

FIGS. 1 and 2A & 2B show a conventional method (hereinafter called a "modified illumination method") recently suggested for exposing a resist by a tilted illumination

method wherein an illumination system provided with a filter between a fly's eye lens and a condenser lens is used. FIG. 1 is a schematic view of the modified illumination system in a conventional projection exposure apparatus, and FIGS. 2A & 2B illustrate shapes of a filter of the system shown in FIG. 1.

Referring to FIG. 1, the modified illumination system is comprised of a conventional illumination apparatus including a light source 1, a projection lens (not shown), a fly's eye lens 2 and a condenser lens 4, with a filter 3 provided thereto. Filter shapes are shown in FIG. 2A for an annular illumination system and in FIG. 2B for a quadruple illumination system. As shown in FIG. 1, vertical incident components of incident light are blocked by filter 3, and only oblique incident components of the light impinge on a mask 5. This is referred as a tilted illumination method.

The tilted illumination method will be explained in more detail referring to FIGS. 3 and 4. FIG. 3 is a simplified view showing a conventional projection exposure method, and FIG. 4 is a simplified view showing a projection exposure method using the above tilted illumination method.

Generally, the illumination light from light source 1 is limited by filter 3 at the exit surface of the fly's eye lens, which coincides with the Fourier transform plane of the mask through the condenser lens. According to the method shown in FIG. 3, the distribution of illumination light on the Fourier transform plane falls within a circular area. Zero-order diffracted light travels along the optical axis (vertical incident component), and +1st-order and -1st-order diffracted

light travel at a diffraction angle θ as shown (oblique incident component). All of these diffracted beams, i.e., the zero-order, +1st-order and -1st-order diffracted light, interfere with one another when forming an image.

5 The diffraction angle θ increases with finer mask patterns. That is, if the sine of θ is larger than the numerical aperture of a projection lens, the +1st-order and -1st-order diffracted light does not pass through the lens, so that only the zero-order diffracted light strikes the surface
10 of a wafer, thus producing no interference. Here, the minimum resolution (R) is defined as

$$R = \frac{\lambda}{2NA}$$

On the other hand, in the above tilted illumination method, the illumination light transmitted through filter 3 illuminates the mask at a specific oblique incident angle,
15 since filter 3 is disposed eccentric of the optical axis. The oblique incident angle α is determined by

$$f(\sin\alpha) = x$$

where x is the distance between the optical axis and the transmissive portion of the filter, and f is the focal length
20 of the condenser lens.

The illumination light is diffracted by the diffraction angle θ with respect to the optical axis. The angles between the path of +1st-order (θ_1) and -1st-order (θ_2) diffracted light and the optical axis have the following relationships:

25 $\sin\theta_1 + \sin\alpha = \lambda/P$

$$\sin\theta_2 + \sin\alpha = \lambda/P$$

wherein P is the line-to-space pitch of the mask.

Higher-order diffracted light takes different paths.

Since the pitch of the pattern is infinitesimally small and

5 the numerical aperture of the projection lens adjacent to the mask is larger than $\sin\theta_2$, the -1st-order and higher-order diffracted light is not admitted to the projection lens.

Consequently, only zero-order and +1st-order diffracted light

makes an image on the wafer surface, and the image contrast is

10 approximately 90% when the mask pattern has line-space duty of 1:1. Here, the resolution (R) is defined as

$$R = \frac{\lambda}{2[NA + \sin\theta_1]}$$

Given 5x projection magnification and a $\sin\theta_1$ value equal to $NA/2$, the resolution limit on the wafer is calculated from

$$\begin{aligned} R &= \frac{\lambda}{2\left(NA + \frac{NA}{2}\right)} \\ &= \frac{\lambda}{3NA} \end{aligned}$$

The resolution limit is 1.5 times higher than that of the
15 conventional projection exposure method. The depth-of-focus is also improved by the tilted illumination method as described above.

In the conventional tilted illumination method, given filter shapes as in FIGS. 2A and 2B the area through which
20 light passes is much smaller than the area where the light is blocked. In FIG. 2A, the ratio of light transmission is

calculated by $(\sigma_0^2 - \sigma_i^2) / \sigma_0^2$, and in general, $\sigma_i = \sigma_0(2/3)$ is known to be the most preferable value wherein a transmission rate is 5/9. Thus, the exposure time is approximately doubled.

Referring to the case shown in FIG. 2B, the transmission ratio is calculated by $4\sigma_i^2 / \sigma_0^2$, where $\sigma_i = (1/4)\sigma_0$, and is 1/4. Thus, the exposure time is increased about four times, thereby reducing the throughput considerably.

That is, since the conventional modified illumination apparatus is comprised of a conventional illumination apparatus and a filter provided thereto wherein the light transmitted to the illumination apparatus is partially blocked, the exposure amount during the modified illumination is too small. Thus, the exposure time becomes too long and errors in the exposure apparatus are generated, which results in the deterioration of uniformity.

Summary of the Invention

It is an object of the present invention to provide an improved projection exposure method which can enhance both resolution and depth-of-focus.

It is another object of the present invention to provide a projection exposure apparatus suitable for performing the above projection exposure method.

It is still another object of the present invention to provide a mask for the projection exposure apparatus.

To achieve the above object, there is provided a projection exposure method using a mask, comprising the steps of: removing vertical components of the light illuminated from

a light source, to thereby generate oblique incident light; and exposing an object by irradiating the oblique incident light onto the mask.

5 The step for transferring the oblique incident light is performed by forming grating patterns to be repeatedly disposed triangles as a basic pattern and to have a phase difference alternately on the upper surface of the mask, or by using a grating mask obtained by forming grating patterns to be repeatedly disposed triangles as a basic pattern and to
10 have a phase difference alternately on a transparent substrate.

The cycle of the grating pattern is preferably between $\lambda/\sin[0.2\sin^{-1}(NA_i)]$ and $\lambda/\sin[0.8\sin^{-1}(NA_i)]$, where NA_i is the numerical aperture of the incident side of the projection
15 exposure apparatus. The oblique incident light is odd-ordered diffracted light, that is, +1st-order and -1st-order.

Another object of the present invention can be achieved by providing a projection exposure apparatus comprising: a light source; first means for irradiating light from a light
20 source onto a mask; and second means for removing vertical incident components of the light between the light source and the mask. Here, the first means includes a condenser lens and the second means is provided between the condenser lens and the mask, the second means is a phase shift chrome-less mask
25 having grating patterns formed thereon to be uniform triangles repeatedly disposed as a basic pattern and to have a phase difference alternately, whereby zero-order diffracted light interferes and is removed by a phase difference of light.

Still another object of the present invention can be achieved by providing a mask comprising a transparent substrate and grating patterns regularly formed on the substrate, whereby light interferes by a phase difference of light so that zero-order diffracted light interferes, to
5 thereby remove the vertical incident components of the light and enhance the oblique incident light components of +1st-order and -1st-order diffracted light.

The grating patterns are formed to be repeatedly disposed
10 triangles as a basic pattern and to have a phase difference alternately. The grating triangle patterns are equilateral, so that the illuminating shape of +1st-order and -1st-order diffracted light is divided into six sub-shapes, or consist of triangles obtained by diagonally dividing rectangles so that
15 the illumination shape of +1st-order and -1st-order diffracted light is divided into eight sub-shapes.

During an exposure process performed by the projection exposure method of the present invention, vertical components of light are removed by mutual interference, and then only
20 oblique incident components of the light remain. That is, zero-order diffracted light and second-order diffracted light are removed by the interference, and all odd-order diffracted light is enhanced. However, diffracted light higher than the third order scarcely exists in practice.

25 Since most of the transmitted light becomes first-order light, the transmission efficiency is enhanced remarkably, compared with that of the conventional method, which results in the improvement of resolution and depth-of-focus.

Brief Description of the Drawings

The above objects and advantages of the present invention will become more apparent by describing in detail a preferred embodiment thereof with reference to the attached drawings in
5 which:

FIG. 1 is a schematic view of a modified illumination system in a conventional projection exposure apparatus;

FIG. 2 illustrates the shapes of a filter provided to the illumination system shown in Fig. 1;

10 FIG. 3 is a simplified view showing a conventional projection exposure method;

FIG. 4 is a simplified view showing a conventional projection exposure method using a modified illumination method;

15 FIG. 5 is a schematic view of an illumination system used for the modified illumination method of the present invention;

FIGS. 6A-6C are simplified views of the optical paths in projection exposure apparatuses, for comparing and explaining the modified illumination method of the present invention
20 (FIG. 6C), a conventional illumination method (FIG. 6A) and the conventional modified illumination method (FIG. 6B);

FIGS. 7A and 7B are cross-sectional views of grating masks of the present invention attached to conventional masks, each of which having patterns formed thereon;

25 FIGS. 8A and 8B are perspective views of the conventional masks having the grating masks attached thereto, which are shown in FIGS. 7A and 7B;

FIGS. 9A and 9B are cross-sectional views of grating

masks of the present invention attached to conventional masks, each of which having patterns formed thereon;

FIGS. 10A and 10B are perspective views of the conventional masks having the grating masks attached thereto, which are shown in FIGS. 9A and 9B;

FIGS. 11A and 11B show another example of grating masks of the present invention attached to conventional masks;

FIGS. 12A and 12B show still another example of grating masks of the present invention attached to conventional masks;

FIG. 13 shows another example of the mask of the present invention;

FIG. 14 shows a further example of the grating mask of the present invention;

FIGS. 15A and 15B are plan views of the grating masks of the present invention shown in FIGS. 8A, 8B, 10A and 10B;

FIGS. 15C and 15D show illumination shapes on the masks shown in FIGS. 15A and 15B;

FIG. 16 is yet another example of the grating mask of the present invention;

FIGS. 17A to 17D are views for explaining an example of a manufacturing method of the mask of the present invention; and

FIG. 18 is a simplified view showing another embodiment of the present invention.

Detailed Description of the Invention

FIG. 5 is a schematic view of an illumination system used for the modified illumination method of the present invention.

A chromeless phase shift mask 12 (hereinafter, called a

"grating mask"), i.e., a dummy mask, having patterns formed to be positioned at regular distances thereon (hereinafter called "grating patterns") that are not resolved onto a wafer is provided above a conventional chrome mask 16 having patterns 5 17 for transfer onto the wafer formed thereon in the modified illumination apparatus (the projection exposure apparatus) shown in FIG. 5. Grating mask 12 is a chrome-less phase shift mask which generates odd-numbered-order diffracted light. By grating mask 12 provided as described above, vertical 10 components 13 of incident light 11 are removed by interference while oblique incident components 14 are enhanced to strike the wafer through conventional chrome mask 16. Accordingly, the use of a grating mask can effect modified illumination, without providing a filter for generating oblique incident 15 light as in a conventional modified illumination method. In addition, although, in the conventional modified illumination method, a portion of light is blocked by a filter, thereby reducing exposure amount, in the present invention, the portion of light which is blocked is small and exposure is 20 accomplished by selectively using the oblique incident components by means of the grating mask, thereby improving optical transmission efficiency.

When a resist exposing process is performed by the modified illumination method of the present invention using 25 the grating mask, a resolution of $3\mu\text{m}$ or below can be achieved, and exposure time is reduced remarkably as compared with that of the conventional modified illumination method using a tilted method.

FIGS. 6A to 6C are simplified views of optical paths in projection exposure apparatuses. Here, FIG. 6A illustrates the conventional illumination method, FIG. 6B illustrates the conventional modified illumination method, and FIG. 6C illustrates the modified illumination method of the present invention. In the above figures, reference numeral 21 denotes a semiconductor wafer as an object to be exposed, reference numeral 23 denotes a projection lens, reference numeral 25 denotes a mask having patterns formed thereon, reference numeral 27 denotes a grating mask, reference numeral 29 denotes a condenser lens, reference numeral 30 denotes a filter through which the light emitted from a light source passes, and reference numeral 31 denotes the filter used for the conventional modified illumination method, as shown in FIG. 2B. The illumination method of FIGS. 6A and 6B is the same as described above.

The projection exposure apparatus of the present invention as described above is provided with grating mask 27 for removing vertical incident components of light between a light source and mask 25.

The principle of enhancing resolution by the use of grating mask 27 is explained as follows.

In the modified illumination method of the present invention, grating mask 27 is fabricated to take a similar structure to that of a phase shift mask in such a way that, of light diffracted through grating mask 27, zero-order diffracted light interferes to be removed while first-order diffracted light is enhanced. Such a grating mask is used so

that oblique incident light having a desired angle illuminates patterns produced.

The resolution of the modified illumination method of the present invention is a function of oblique incident angle θ_1 of light with respect to mask 25, as in the conventional tilted illumination method of the modified illumination method. Assuming that the cycle of the grating pattern on grating mask 27 is P_g , the angle of oblique incident light θ_1 and the maximum resolution R are expressed as

$$\theta_1 = \sin^{-1}\left(\frac{\lambda}{P_g}\right)$$

$$R = \frac{\lambda}{2NA\left(1 + \sin\frac{\theta_1}{NA}\right)}$$

$$= \frac{\lambda}{2NA(1+\alpha)}$$

Here, α is substituted for $\sin\theta_1/NA$.

In the conventional modified illumination method, α cannot be equal to σ and more. However, α is not set in the illumination method of the present invention and may have a value of up to "1" by adjusting grating size.

The grating pattern cycle is determined as follows.

The maximum angle θ which is acceptable to an exposure system can be expressed as $\theta = \sin^{-1}(NA_i)$, wherein NA_i is the numerical aperture of the incident side, and an angle of 0.2-0.8 times as large as θ is necessary for excellent resolution.

Accordingly, the grating pattern cycle is preferably between $\lambda/\sin[0.2\sin^{-1}(NA_i)]$ and $\lambda/\sin[0.8\sin^{-1}(NA_i)]$, wherein λ

represents the wavelength of the used light, and NA_i represents the numerical aperture of the incident side of the exposure apparatus.

5 Since the grating pattern cycle depends on the sensitivity and resolution of the photoresist to be used, optimization is necessary for achieving maximum effect. However, in general, under the assumption that 0.5 times is the optimum, the necessary grating pattern cycle P on the mask is given by

$$P = \frac{\lambda}{\sin[0.5\sin^{-1}(NA_i)]}$$

$$= \frac{\lambda}{\sin\beta}$$

10 wherein λ represents the wavelength of the used light, and NA_i represents the numerical aperture of the incident side of the exposure apparatus. Here, β is substituted for $0.5\sin^{-1}(NA_i)$.

Referring to the attached drawings, the grating mask will be described in more detail by the following embodiments.

15 FIGS. 7A & 7B and 9A & 9B are cross-sectional views of grating masks of the present invention attached to conventional masks having patterns formed thereon. FIGS. 8A and 8B are perspective views showing the conventional masks having the grating masks attached thereto, which are shown in
20 FIGS. 7A and 7B. FIGS. 10A and 10B are perspective views showing the conventional masks having the grating masks attached thereto, which are shown in FIGS. 9A and 9B.

In FIGS. 7A & 7B, 8A & 8B, 9A & 9B and 10A & 10B, reference numeral 41 denotes a conventional mask substrate,

reference numeral 43 denotes a pattern for defining an exposure region comprised of chrome, reference numeral 45 denotes a grating mask substrate, reference numeral 47 denotes a grating pattern, reference numeral 49 denotes an adhesive supporting band for a grating mask, and reference numeral 51 denotes a double-sided adhesive tape that binds the grating mask and a conventional mask.

The grating mask including grating mask substrate 45 and grating patterns 47 formed thereon is obtained by forming grating patterns 47 on grating mask substrate 45 which is comprised of quartz, soda-lime glass or BPSG. Grating pattern 47 is formed using a conventional method for forming a mask pattern. Grating pattern 47 can be formed by using a photoresist, by patterning using spin-on-glass, or by patterning the rear surface of grating mask substrate 45 comprised of quartz. At this time, the thickness (t) of grating pattern 47 is determined so that the light transmitting the grating mask has a phase difference of 180° in accordance with the used wavelength, mask material and pattern material. Thus, the optical path difference D can be calculated by the following equation:

$$D = \frac{2\pi t(n-1)}{\lambda}$$

wherein n is a refractive index of the pattern material, and λ is the wavelength of the used light.

Since the light path difference for achieving interference is equal to π , the thickness (t) of the pattern

can be determined by

$$t = \frac{\lambda}{2(n-1)}$$

Grating pattern 47 is formed to have a regular distance, as described above.

FIGS. 7A and 9A illustrate grating masks attached to conventional masks so that the surfaces of the grating masks on which grating patterns 47 are formed face the rear surfaces of the conventional masks. FIGS. 7B and 9B illustrate grating masks attached to conventional masks so that the surfaces of the grating masks on which no grating patterns 47 are formed face the rear surfaces of the conventional masks. Thus, a grating mask of the present invention can be attached to a conventional mask by using either of the methods shown in FIGS. 7A and 7B.

Such an attachment of grating mask substrate 45 to conventional mask substrate 41 may be performed by using an epoxy resin, an adhesive substance, a silicon caulking or double-sided adhesive tape. The attachment of grating mask substrate 45 and conventional mask substrate 41 may be performed by a melting-adhering method or a clamping method using a quartz clamp.

Further, the separating space between grating mask substrate 45 and conventional mask substrate 41 is preferably 1.0 μ m or more in order to prevent the two masks from abrading each other during the attachment step. In such a case, thick adhesive tape as shown in FIG. 7B or pellicle frame can be

used as adhesive supporting band 49. At this time, the space between grating mask substrate 45 and conventional mask substrate 41 may even be up to several tens of millimeters.

FIGS. 11A and 11B are perspective views showing another example of grating masks of the present invention attached to conventional masks. Reference numeral 53 denotes a pellicle frame with all the other reference numerals having the same representation as in FIGS. 7A and 7B. Grating mask substrate 45 is attached to conventional mask substrate 41 by adhesive supporting band 49, as shown in FIG. 7A. In FIGS. 11A and 11B, pellicle frame 53 is used as the adhesive supporting band of FIG. 7A. FIG. 11A illustrates an attachment step that after attaching pellicle frame 53 to conventional mask substrate 41, the grating mask is attached to pellicle frame 53. The mask shown in FIG. 11B is the same as that shown in FIG. 11A, except that grating mask substrate 45 has been cut to be the same size as that of pellicle frame 53 and attached to pellicle frame 53.

A new pellicle is not necessary for pellicle frame 53, because a frame can be detached from an old pellicle for pellicle frame 53. Thus, abrasion between the two masks can be prevented by using pellicle frame 53 as a supporting band of grating mask substrate 45, and the pellicle frame can be reused to promote conservation.

FIGS. 12A and 12B are perspective views showing still another example wherein grating masks of the present invention are attached to conventional masks. Like elements are labelled with the same reference numerals shown in FIGS. 11A and 11B.

The grating mask shown in FIG. 12A is the same as that of FIG. 11A, except that it is thinner. Grating mask substrate 45 can be made thinner by forming grating pattern 47 on a conventional substrate ground by repeated lapping and polishing prior to formation of grating pattern 47, or by grinding the rear surface of grating mask substrate 45 through lapping and polishing after forming grating pattern 47 on grating mask substrate 45 while protecting the portion where grating pattern 47 has been formed by a polymer coating process.

The mask shown in FIG. 12B is the same as that of FIG. 10A, except that after forming grating pattern 47 on grating mask substrate 45 comprised of quartz, grating mask substrate 45 has been cut and then grating mask substrate 45 has been attached to conventional mask substrate 41.

FIG. 13 shows still another example of the mask of the present invention. The mask shown in Fig. 13 is obtained by forming grating patterns 47 on the rear surface of conventional mask substrate 41 having conventional chrome patterns 43 formed thereon. Grating pattern 47 can be formed by a conventional photo process when a photoresist is used. When grating pattern 47 is formed by using a material as spin-on glass or by etching the substrate itself. In such a case, mask etching equipment is necessary.

FIG. 14 illustrates a further example of the grating mask of the present invention. The grating mask shown in FIG. 14 is the same as that of FIG. 8B, except that grooves 55 through which mask alignment light passes are formed in the edge

portion of grating mask substrate 45.

When the exposure is performed by superposing a grating mask on a conventional mask as shown in FIG. 8B, the light intensity may be lowered or the light can be reflected from the interface of the masks, since the mask alignment light has to pass through grating mask substrate 45 and conventional mask substrate 41. In such a case, errors occur because the light cannot be sensed. Therefore, in order to prevent such a problem, groove 55 is preferably formed by cutting the edge portion of grating mask substrate 45 through which the mask alignment light passes. This groove may be formed using an ultrasonic cutter or a dicing machine.

FIGS. 15A and 15B are plan views of the grating masks of the present invention shown in FIGS. 8A & 8B and 10A & 10B, and FIGS. 15C and 15D illustrate illumination shapes on the masks of FIGS. 15A and 15B.

The grating patterns shown in FIGS. 15A and 15B are comprised of isosceles triangles obtained by diagonally dividing regular quadrilaterals or equilateral triangles, which produce an eight-dot or six-dot illumination shape during a practical illumination, as shown in FIGS. 15C and 15D. Accordingly, when projecting patterns onto a wafer during a practical process, remarkable resolution and depth-of-focus are obtained in patterns formed on the wafer in any direction including parallel or perpendicular to the grating patterns.

FIG. 16 illustrates yet another example of the grating mask of the present invention. The grating mask shown in FIG. 16 is the same as that of FIG. 7A, except that grating mask

substrate 45 is larger than conventional mask substrate 41. In such a case, the manual operation of the exposure apparatus is easy.

A method for manufacturing a mask of the present invention will be described in more detail with the following embodiments.

Embodiment 1

FIGS. 17A to 17D are views for explaining an example of a method for manufacturing the mask of the present invention.

FIG. 17A illustrates a step of forming a grating pattern 63. A photoresist film is formed on a quartz wafer 61 whose diameter is six inches and whose thickness is 0.1-1mm, by coating a photoresist to a thickness of 0.1-1 μ m. Then, a photoresist pattern (not shown) for forming grating pattern 63 is formed by patterning using NSR-1505i74 (Nicon model number), and then a checkerboard type grating pattern 63 as shown, is formed by etching quartz wafer 61. After a cleaning process, the remaining photoresist pattern is stripped away.

FIG. 17B illustrates a step of cutting a quartz wafer to thereby form a grating mask. Quartz wafer 61 on which grating pattern 63 has been formed is cut using a dicing machine or a diamond knife so as to be fit to the size of a pellicle frame, and then a grating mask substrate 65 on which grating pattern 63 is formed is obtained. Then, cleaning is performed.

FIG. 17C illustrates a step of attaching grating mask substrate 65 obtained in the above step, to a pellicle frame 67. Pellicle frame 67 having a size of 98mm $\times$ 120mm $\times$ 4mm is used.

After separating pellicle frame 67 from a damaged pellicle, double-sided adhesive tape is coated on the upper and lower rim of pellicle frame 67, and then grating mask substrate 65 is glued to pellicle frame 67 in a clean room.

5 FIG. 17D illustrates a step of attaching grating mask substrate 65 to a conventional mask substrate 69 on which conventional chrome patterns 71 are formed. After grating mask substrate 65 is glued to the one side of pellicle frame 67, conventional mask substrate 69 whose size is 5"x5"x0.09" is
10 attached to grating mask substrate 65 so that the surface of grating mask substrate 65 on which grating patterns 63 are not formed faces the rear surface of conventional mask substrate pattern 69 (continuously in the clean room), to thereby obtain a mask of the present invention.

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Embodiment 2

FIG. 18 is a simplified view showing another embodiment of the present invention.

After coating a pellicle manufacturing material such as
20 nitro-cellulose to a thickness of 2-3 μ m on a grating mask having the grating patterns obtained in Embodiment 1, a mask film 83 on which grating patterns 85 have been imaged is obtained. Thereafter, mask film 83 is attached to a conventional mask substrate 81 using the same pellicle frame
25 87 as in Embodiment 1, in the same manner as in Embodiment 1.

Embodiment 3

A photoresist is coated to a thickness of approximately

0.1-1 μ m on the rear surface of quartz mask substrate on which conventional chrome patterns are formed, to thereby form a photoresist layer. Thereafter, grating patterns are projected by using an electron beam exposure system. Then, processes such as a development, a quartz etching, and a photoresist pattern stripping are performed to obtain a mask of the present invention having grating patterns formed on one surface of the mask substrate and conventional chrome patterns formed on the other surface of the mask substrate, as shown in FIG. 10.

Embodiment 4

A grating mask is obtained by forming grating patterns on a quartz grating mask substrate whose size is 5"x5"x0.09" as described in Embodiment 1 or 3. Then, the grating mask is attached to a same-sized conventional mask substrate using a pellicle frame in the same manner as in Embodiment 1, to thereby obtain a mask of the present invention as shown in FIG. 9A.

Embodiment 5

The mask of the present invention is obtained by performing the same process, adding the step of grinding the grating mask substrate 0.09" thick, which is obtained in Embodiment 4, to have a thickness of 0.03" after lapping and polishing.

As described above, grating patterns of the present invention are formed to be equilateral triangles or isosceles

triangles obtained by diagonally dividing regular rectangles so that the illumination shape of +1st-order and -1st-order diffracted light is divided into six or eight sub-shapes.

Thus, when projecting patterns onto a wafer, outstanding

5 improvement of resolution and depth-of-focus is achieved in patterns in any direction including parallel or perpendicular to grating patterns.

Since in the illumination method of the present invention, little loss of light exists during a light
10 transmission, compared with in the conventional illumination method with a filter, transmission efficiency increases by 200-400% and the throughput is improved due to the same tilted illumination effect obtained as in the conventional method as well.

15 Additionally, in the present invention light is not blocked and thus deterioration of uniformity does not occur since a filter is not used, while the reverse effect is achieved in the conventional method using a filter.

Further, excellent modified illumination can be effected
20 by additionally providing a grating mask and forming patterns on a conventional mask, and no alignment between a grating mask and a conventional mask for pattern transfer is necessary. Therefore, a mask of high resolution can be manufactured with low cost and higher resolution can be
25 realized through optimization in accordance with patterns.

The mask of the present invention prevents abrasion by attaching a grating mask to a conventional mask using a pellicle frame as a supporting band between the grating mask

and the conventional mask.



What is claimed is:

1. A projection exposure method using a mask comprising the steps of:
 - removing vertical components of the light illuminated from a light source, to thereby generate oblique incident light; and
 - exposing an object by irradiating said oblique incident light onto said mask.
2. A projection exposure method using a mask according to claim 1, wherein said step for transferring said oblique incident light is performed by forming grating patterns to be repeatedly disposed triangles as a basic pattern and to have a phase difference alternately on the upper surface of said mask.
3. A projection exposure method using a mask according to claim 1, wherein said step for transferring said oblique incident light is performed by using a grating mask in which grating patterns are formed to be repeatedly disposed triangles as a basic pattern and to have a phase difference alternately on a transparent substrate.
4. A projection exposure apparatus comprising:
 - a light source;
 - first means for irradiating light from said light source onto a mask;
 - and second means for removing vertical incident components of the light between said light source and said mask.
5. A projection exposure apparatus according to claim 4,



wherein said second means is a phase shift chrome-less mask having grating patterns formed thereon to be uniform triangles repeatedly disposed as a basic pattern and to have a phase difference alternately, whereby zero-order diffracted light
5 interferes and is removed by a phase difference of light.

6. A mask comprising:

a transparent substrate; and

grating patterns regularly formed on said substrate, whereby light interferes by a phase difference of light so
10 that zero-order diffracted light interferes, to thereby remove the vertical incident components of light and enhance the oblique incident light components of +1st-order and -1st-order diffracted light.

7. A mask according to claim 6, wherein said grating
15 patterns are formed to be repeatedly disposed triangles as a basic pattern and to have a phase difference alternately.

8. A mask according to claim 7, wherein said grating triangle patterns are formed to be equilateral ones so that the illuminating shape of +1st-order and -1st-order diffracted
20 light is divided into six sub-shapes.

9. A mask according to claim 7, wherein said grating triangle patterns are formed to be triangles obtained by diagonally dividing rectangles so that the illumination shape of +1st-order and -1st-order diffracted light is divided into
25 eight sub-shapes.