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(54) **PROJECTION EXPOSURE APPARATUS**

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(51) **Int. Cl.**

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G03B 27/54	(2006.01)
G03B 27/72	(2006.01)

(52) **U.S. Cl.** **355/53**; 355/67; 355/71

(58) **Field of Classification Search** 355/53, 355/67, 71; 430/5

See application file for complete search history.

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(57) **ABSTRACT**

A projection exposure apparatus includes illuminating optical means for illuminating a projection negative, and projection optical means for projection-exposing the projection negative illuminated by the illuminating optical means onto a substrate, the illuminating optical means including light source means for supplying exposure light, annular light source forming means for forming an annular secondary light source by the light from the light source means, and condenser means for condensing the light beam from the annular light source forming means on the projection negative, and is designed to satisfy the following condition:

$$\tfrac{1}{3} \leq d_1/d_2 \leq \tfrac{2}{3},$$

where d_1 is the inner diameter of the annular secondary light source, and d_2 is the outer diameter of the annular secondary light source.

82 Claims, 8 Drawing Sheets

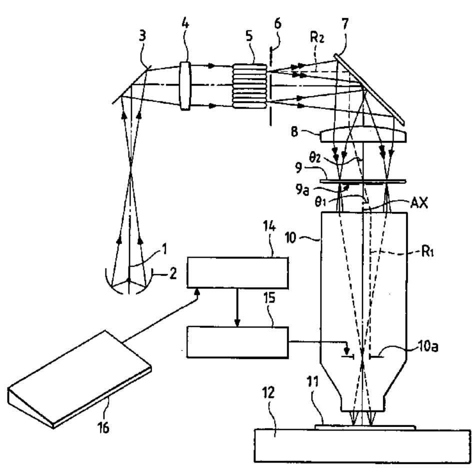

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FIG. 1

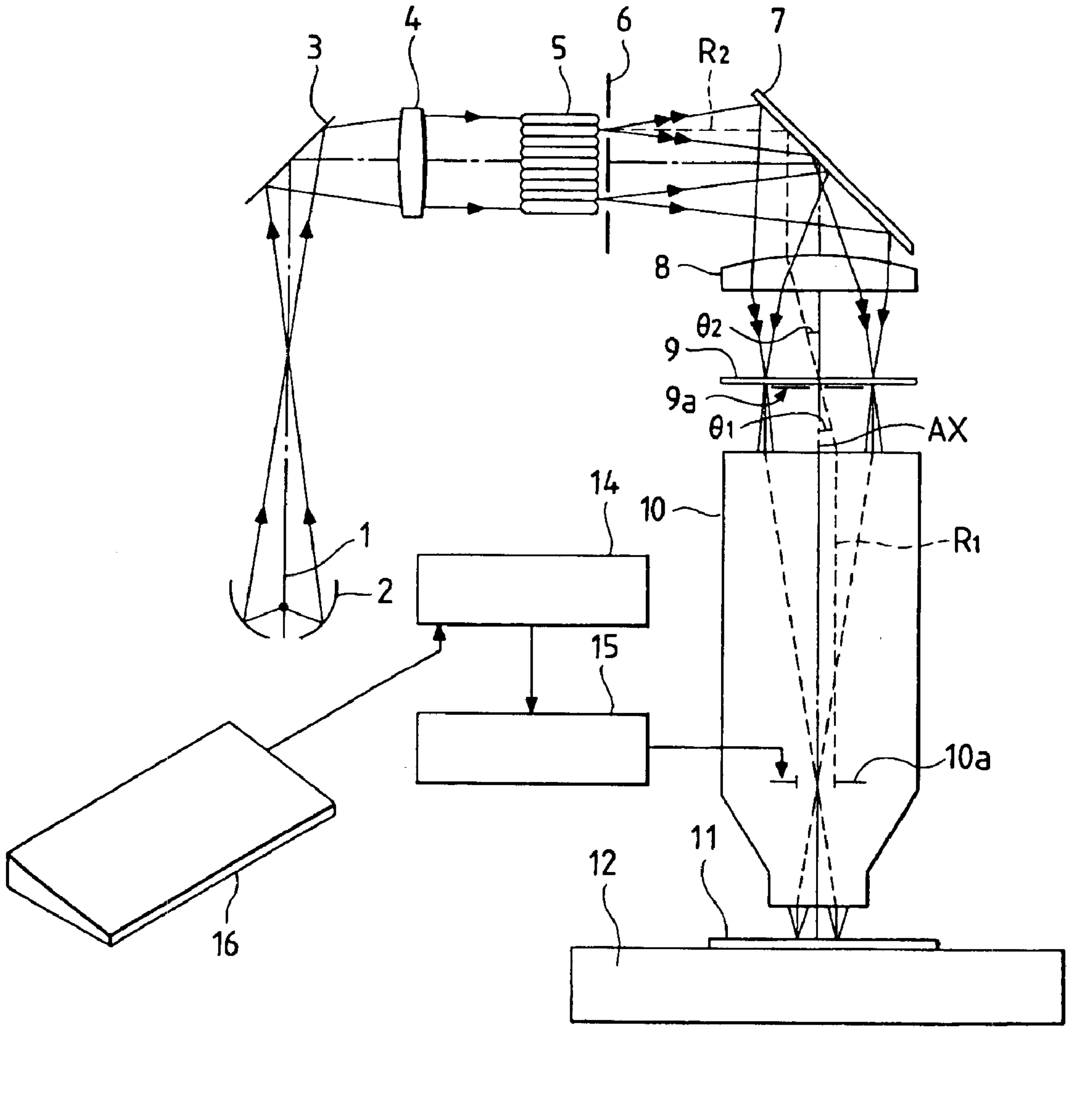


FIG. 2

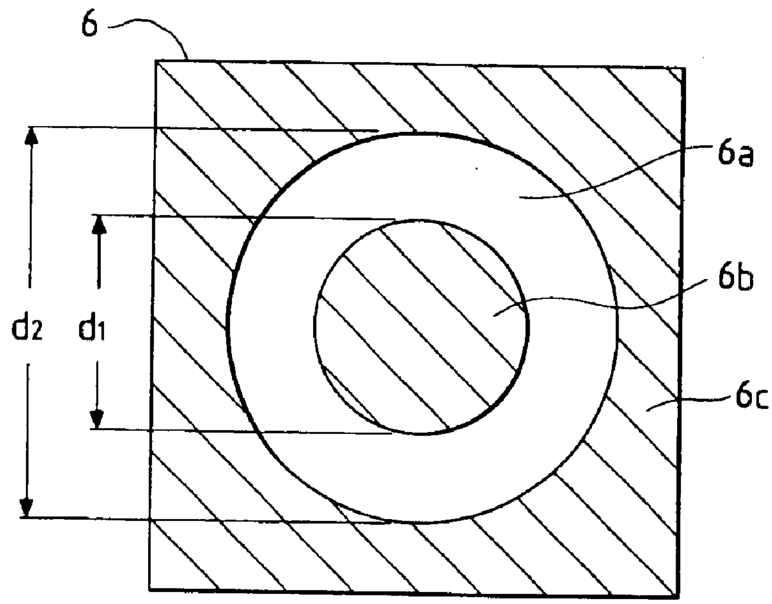


FIG. 3

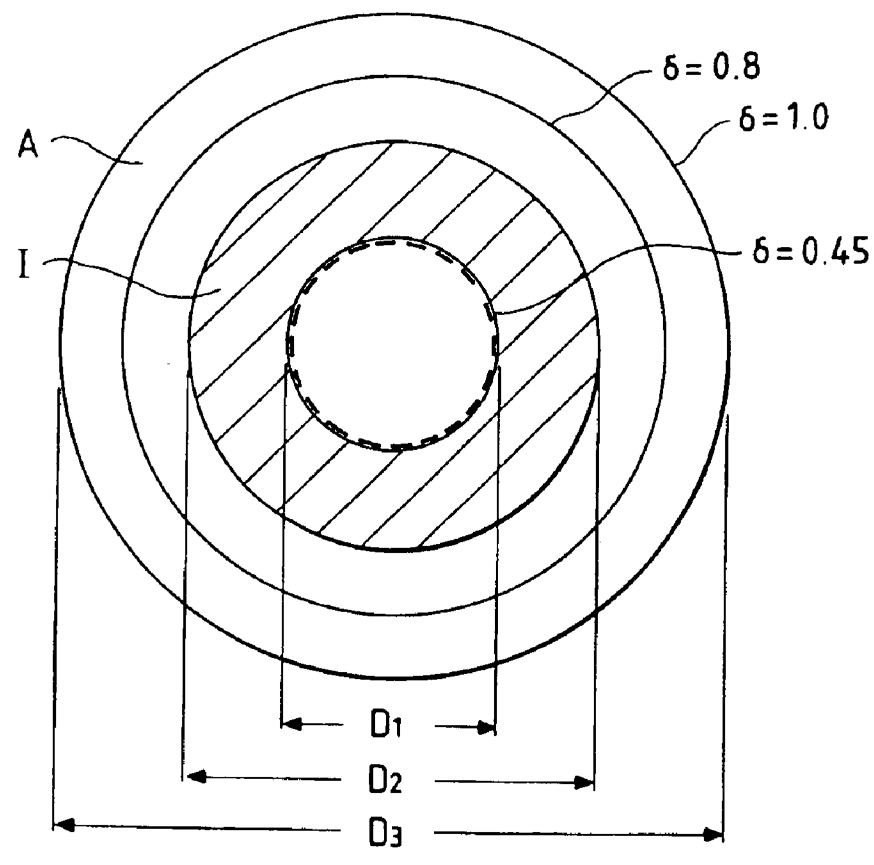


FIG. 4

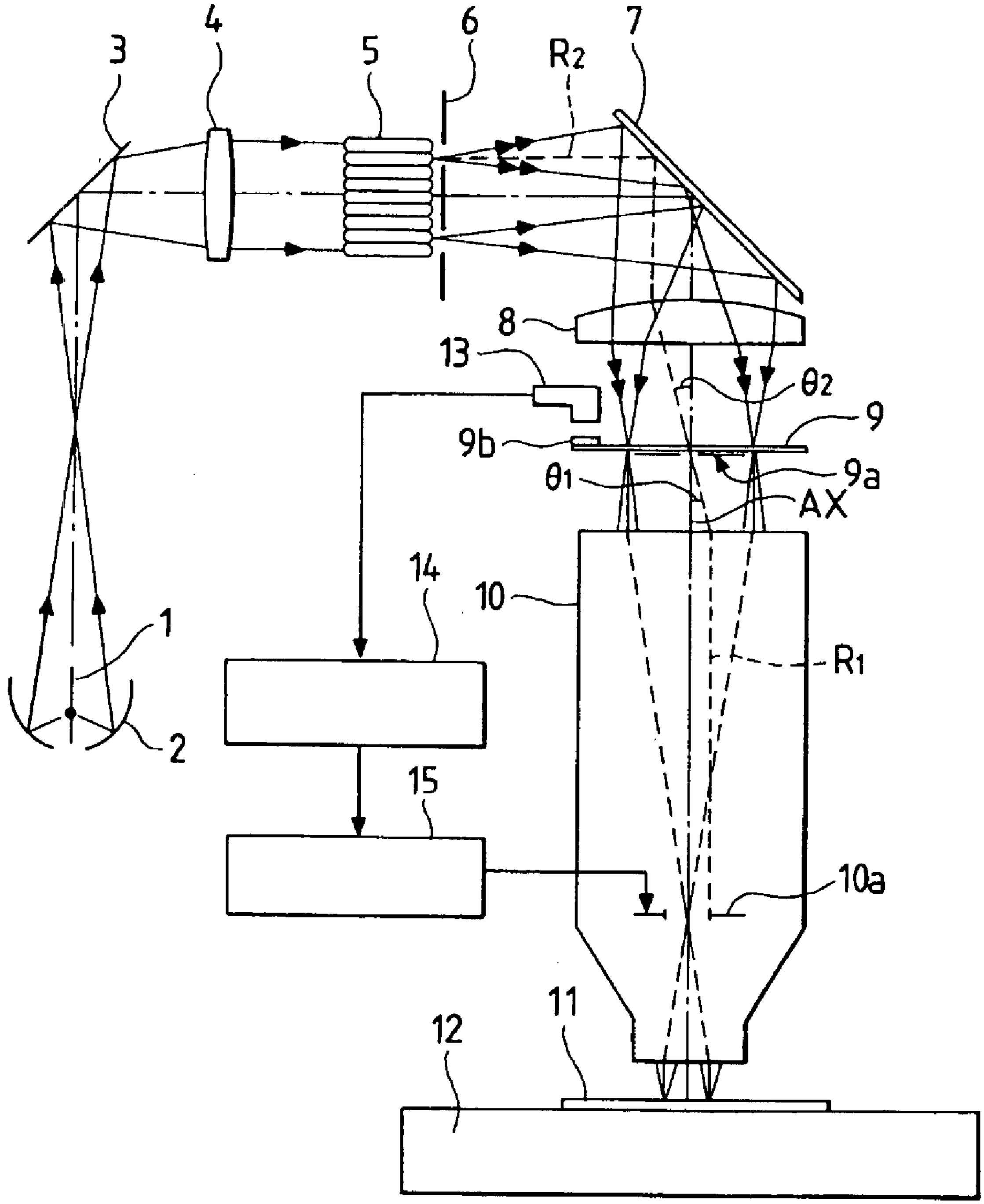
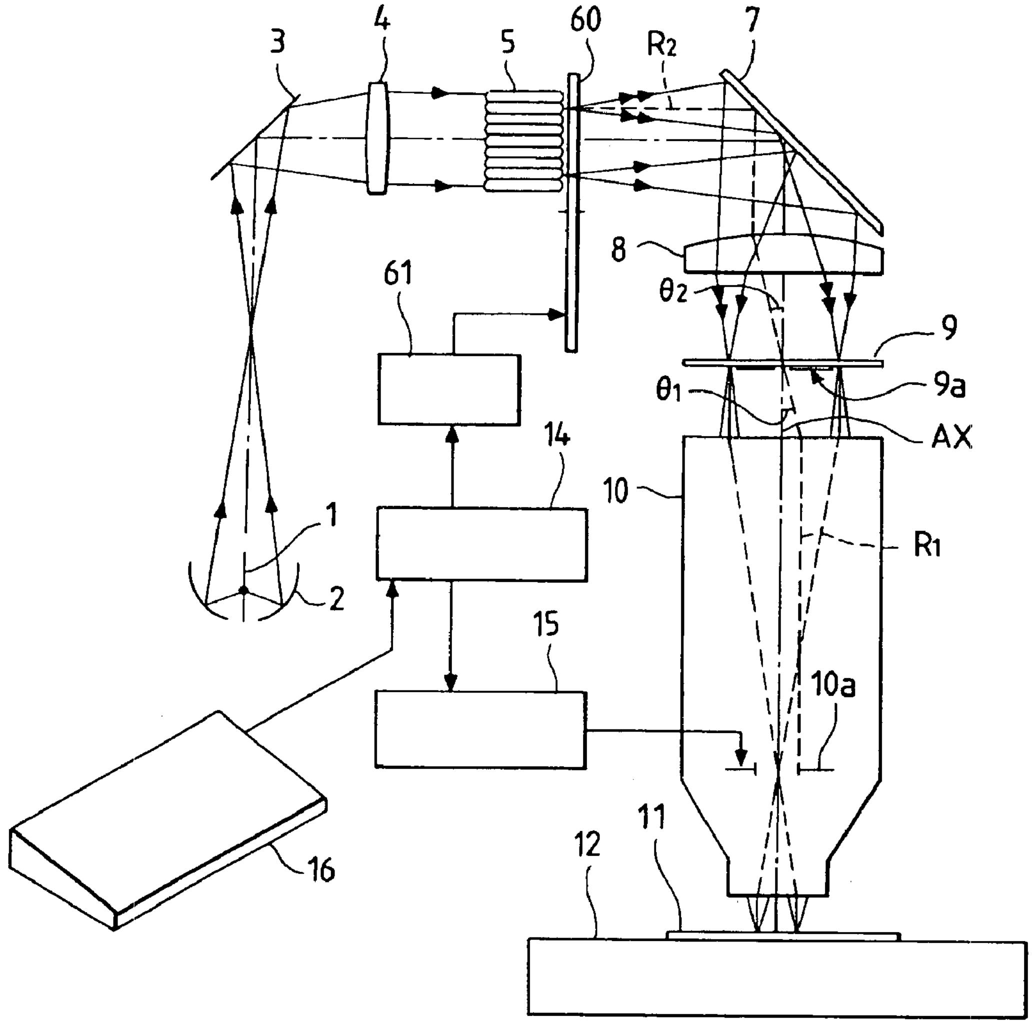
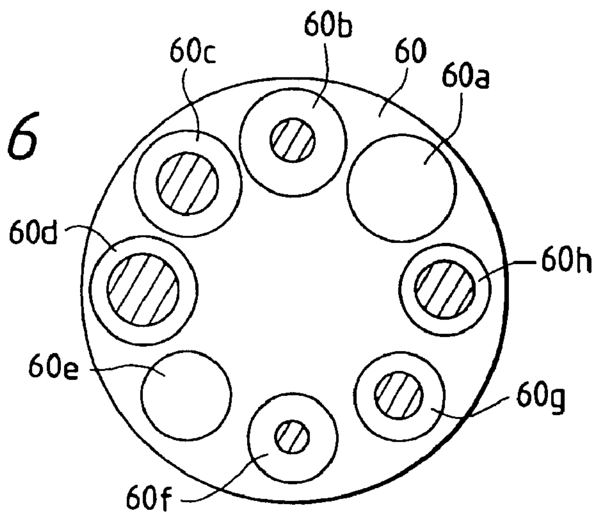


FIG. 5



3
4
5
60
R2
7
8
θ2
9
9a
θ1
AX
61
14
1
2
10
R1
15
10a
12
11
16

FIG. 6



60b
60c
60
60a
60d
60h
60e
60g
60f

FIG. 7

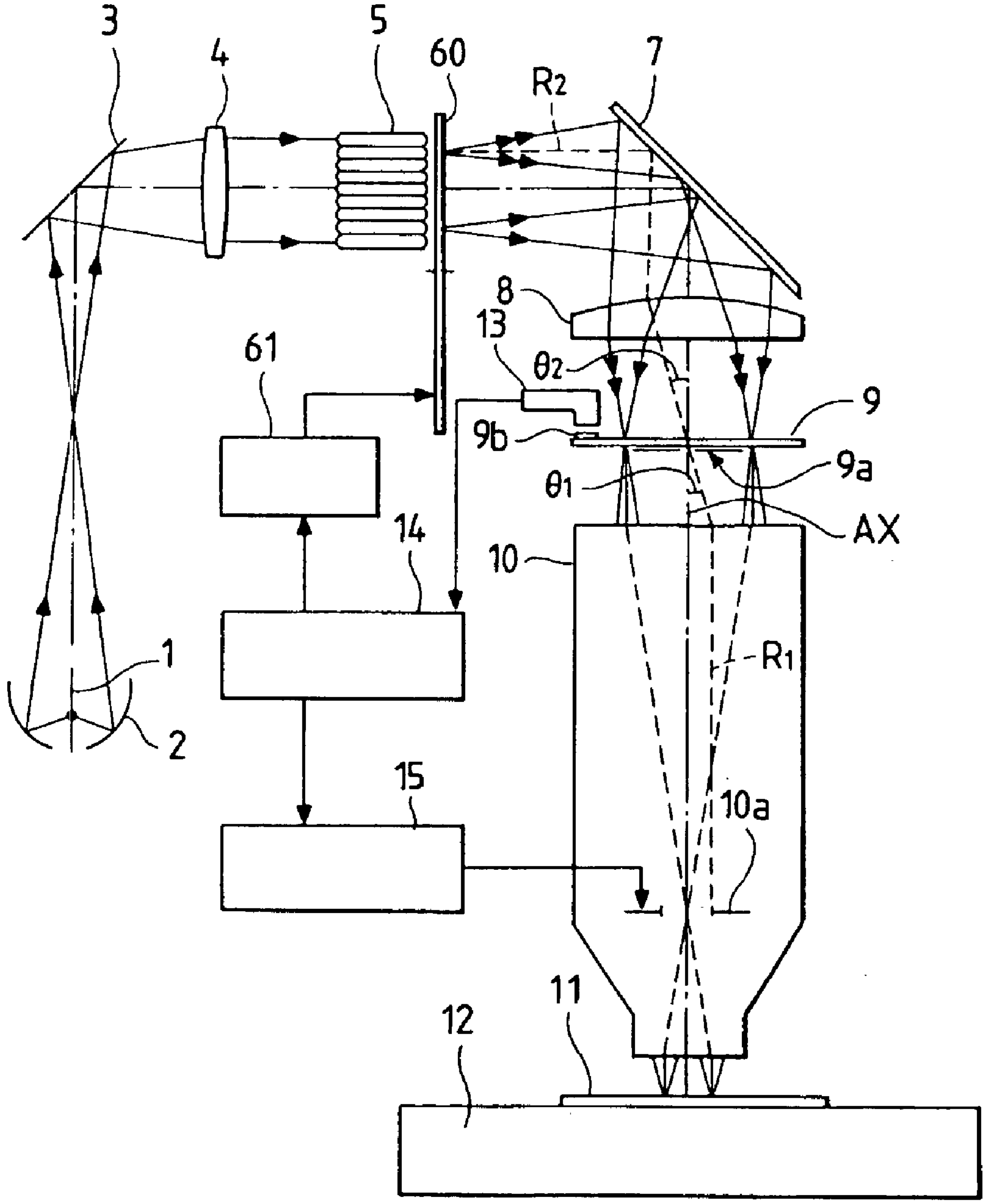


FIG. 8

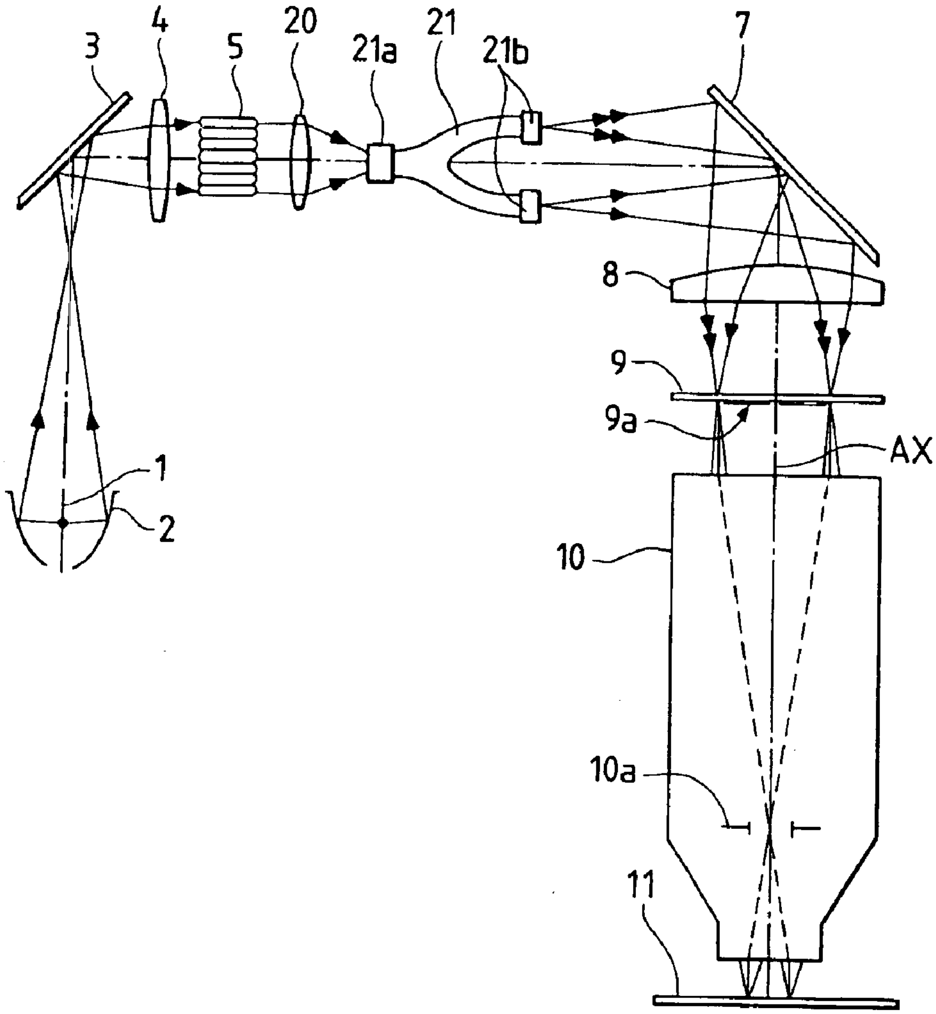


FIG. 9

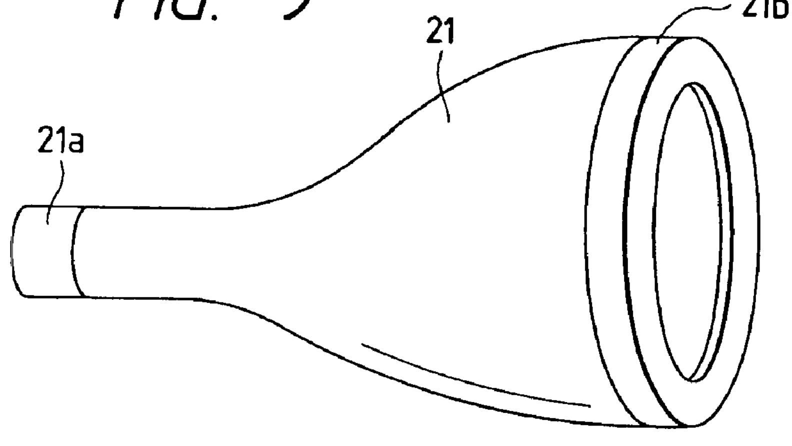


FIG. 10

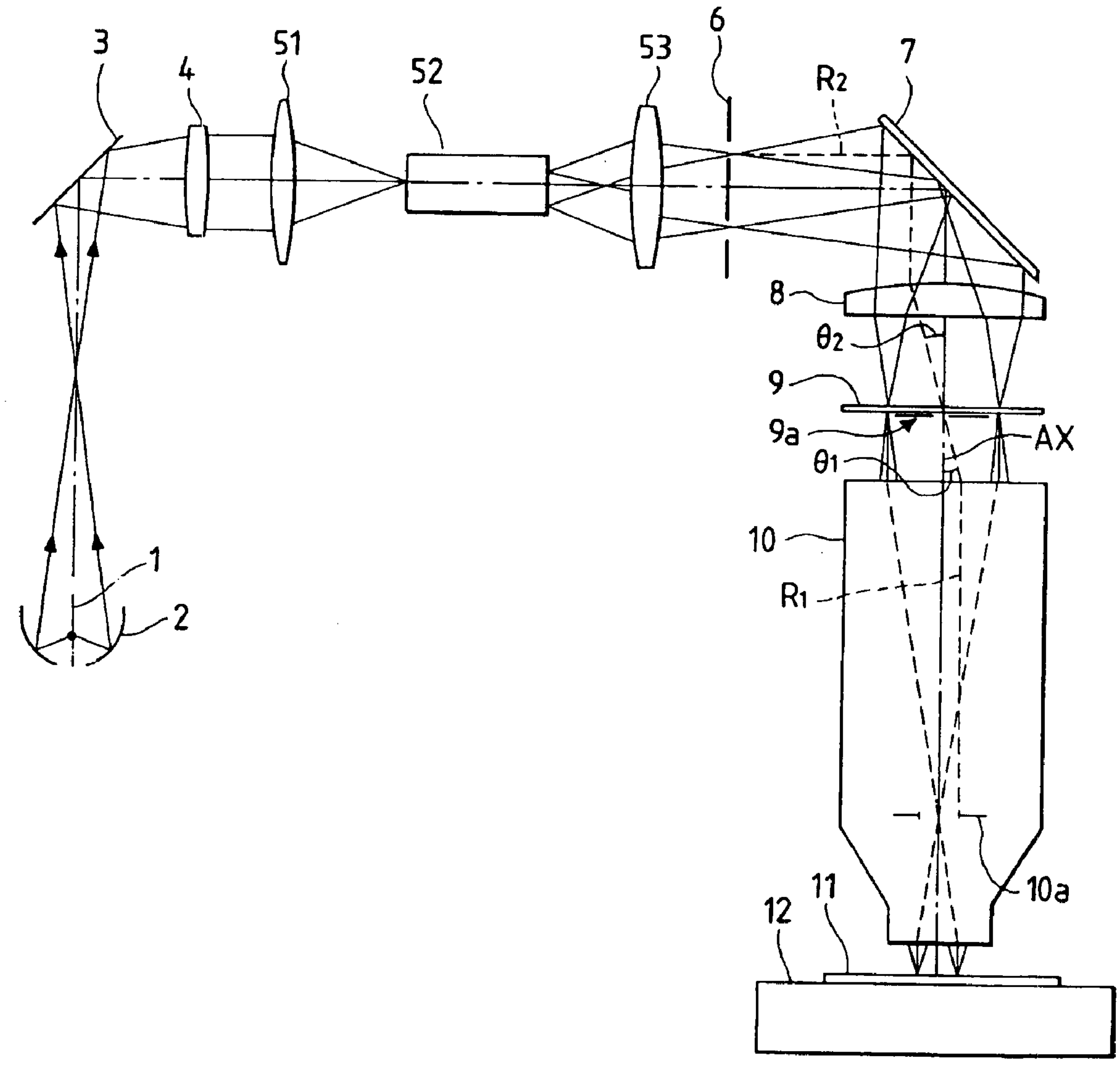
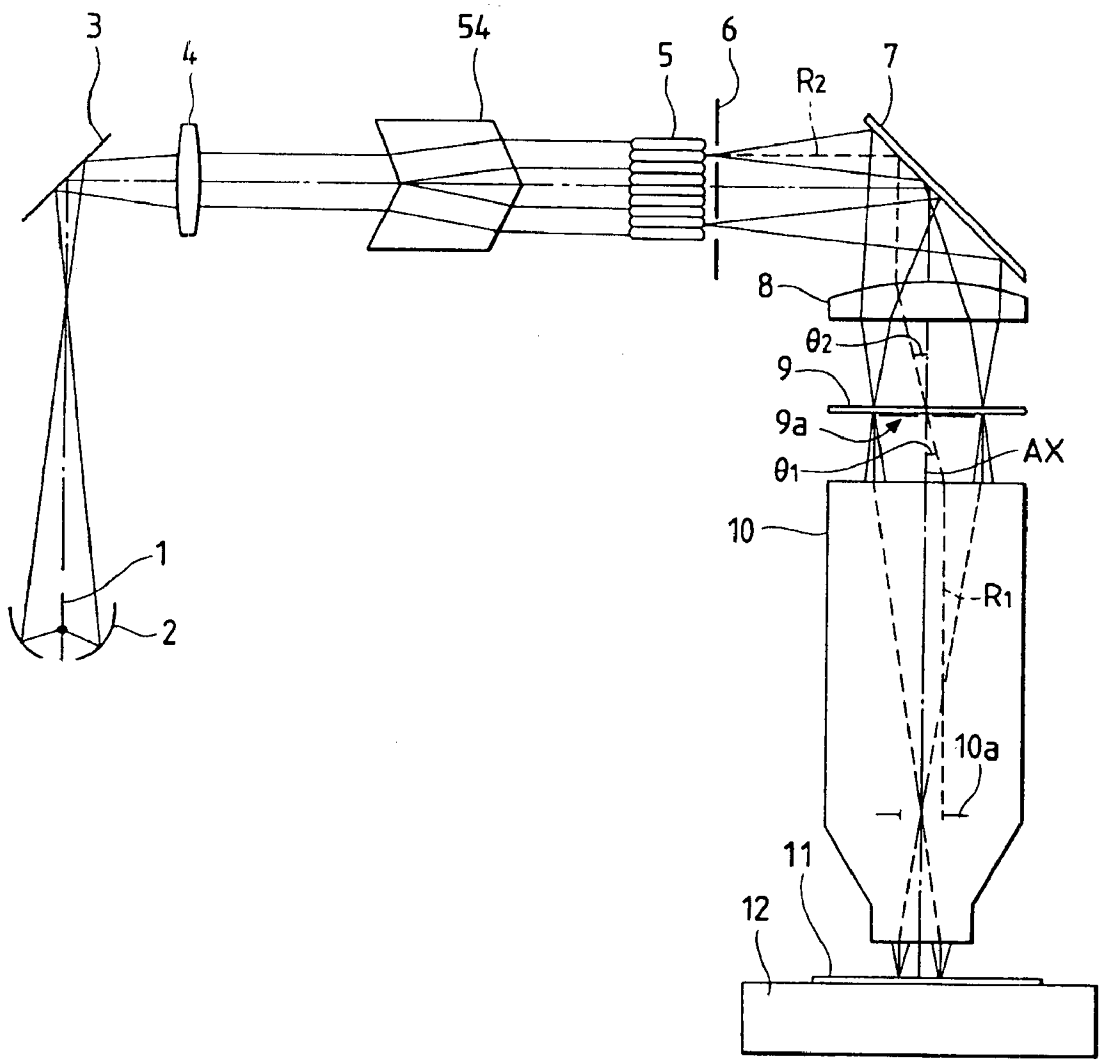


FIG. 11



PROJECTION EXPOSURE APPARATUS

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

[This is a continuation of application Ser. No. 08/274,369 filed Jul. 13, 1994, which is a continuation-in-part of application Ser. No. 08/166,153 filed Dec. 14, 1993, which is a continuation of application Ser. No. 07/991,421 filed Dec. 16, 1992, all now abandoned.] *This reissue application is a continuation of application Ser. No. 09/103,536, filed Jun. 24, 1998 abandoned, for reissue of U.S. Pat. No. 5,530,518, which issued from application Ser. No. 08/370,216, which is a continuation of application Ser. No. 08/274,369 filed Jul. 13, 1994, abandoned, which is a continuation-in-part of application Ser. No. 08/166,153 filed Dec. 14, 1993, abandoned which is a continuation of application Ser. No. 07/991,421 filed Dec. 16, 1992, abandoned.*

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a projection exposure apparatus for projection-exposing minute patterns necessary for the manufacture of semiconductive integrated circuits or the like onto a substrate (wafer).

2. Related Background Art

As a prior-art projection exposure apparatus, there is known one in which exposure light is applied to a projection negative such as a mask or a reticle (hereinafter referred to as the reticle) on which a circuit pattern is formed, and the image of the circuit pattern on the reticle is transferred onto a substrate such as a wafer (hereinafter referred to as the wafer) through a projection optical system.

Here, resolving power representative of a line and space pattern transferred onto the wafer is theoretically of the order of $0.5\times\lambda\times NA$ when the wavelength of the exposure light is λ and the numerical aperture of the projection optical system is NA.

In the actual lithography process, however, a certain degree of depth of focus becomes necessary due to the influence of the curvature of the wafer, the level difference of the wafer by the process, etc. or the thickness of photoresist itself. Therefore, practical resolving power to which a factor such as the depth of focus has been added is expressed as $k\times\lambda\times NA$, where k is called a process coefficient and is usually of the order of 0.7–0.8.

Now, in recent years, particularly the tendency toward the minuteness of patterns transferred onto wafers is advancing and as a technique for coping with this tendency toward the minuteness, it is conceivable to shorten the wavelength of exposure light or to increase the numerical aperture NA of the projection optical system, as is apparent from the above-expression of the resolving power.

However, in the technique of shortening the wavelength of exposure light, glass materials usable for the lenses of the projection optical system become limited with the shortening of the exposure light, and it is difficult to design a projection optical system in which aberrations have been sufficiently corrected, in such limited glass materials.

Also, in the technique of increasing the numerical aperture NA of the projection optical system, an improvement in resolving power can be surely achieved, but the depth of focus of the projection optical system is inversely proportional to the square of the numerical aperture NA of the projection optical system. Accordingly, the depth of focus decreases remarkably, and this is not preferable. Moreover, it is difficult to design a projection optical system which has a great numerical aperture NA and yet in which aberrations have been sufficiently corrected.

SUMMARY OF THE INVENTION

So, it is an object of the present invention to eliminate the above-noted problems and to provide a projection exposure apparatus in which the depth of focus of a projection optical system is improved, whereby in practical use, a circuit pattern on a reticle can be faithfully transferred onto a wafer with a higher resolution.

To achieve the above object, a projection exposure apparatus according to an embodiment of the present invention includes illuminating optical means for illuminating a projection negative, and projection optical means for projection-exposing the projection negative illuminated by the illuminating optical means onto a substrate, the illuminating optical means including light source means for supplying exposure light, annular light source forming means for forming an annular secondary light source by the light from said light source means, and condenser means for condensing the light beam from said annular light source forming means on the projection negative, and is designed to satisfy the following condition:

$$\tfrac{1}{3}\leqq d_1/d_2\leqq\tfrac{2}{3}, \quad (1)$$

where d_1 is the inner diameter of the annular secondary light source, and d_2 is the outer diameter of the annular secondary light source.

As described above, the projection exposure apparatus according to an embodiment of the present invention is designed to illuminate the reticle by the exposure light from the light source means, i.e., effect so-called annular illumination (or inclined illumination).

At this time, the annular secondary light source of the annular light source forming means is designed to satisfy the above-mentioned conditional expression (1), whereby the depth of focus of projection means can be improved to achieve an improvement in practical resolution.

When as an example, the wavelength λ of light source means is i-line (365 nm) and the wafer side numerical aperture NA of a projection lens is 0.4, the line width which can be resolved by a prior-art exposure apparatus in which the process coefficient is 0.7 is of the order of 0.64 μm from $k\times\lambda/NA$, while in the projection exposure apparatus according to an embodiment of the present invention, the process coefficient k is of the order of 0.5 and therefore, the line width which can be resolved is 0.46 μm. Thus, it will be seen that in the projection exposure apparatus according to the present invention, an improvement in resolution after a practically more sufficient depth of focus than in the prior-art apparatus has been secured is achieved.

If the lower limit of the above condition (1) is exceeded, the inner diameter of the annular second light source becomes too small, and the effect or advantage caused by the annular illumination according to the invention is reduced so that it is difficult to improve depth of focus as well as resolution of the projection optical system.

If the upper limit of the condition (1) is exceeded, the width of each line forming a pattern or patterns on a reticle, which width is uniform and the same, becomes uneven or varied depending on repetition of the lines or line-to-line distances of the pattern when transferred onto the wafer, and accordingly it is not possible to transfer the pattern on the reticle onto the wafer accurately.

Further, if the upper limit of the condition (1) is exceeded, change in line width for change in exposure amount is enlarged and it is difficult to form a pattern of a desired line width on the wafer.

Further, to sufficiently bring out the effect of annular illumination according to the present invention, it is desirable that when the projection negative side numerical aperture of the projection optical means is NA_1 and the numerical aperture of the illuminating optical means determined by the outer diameter of the annular secondary light source is NA_2, the projection exposure apparatus according to the present invention be designed to the following conditional expression (2):

$$0.45 \leqq NA_2/NA_1 \leqq 0.8 \quad (2)$$

If the lower limit of this conditional expression (2) is exceeded, the angle of incidence of the light which inclination-illuminates the reticle by annular illumination will become small and the effect of annular illumination according to the present invention can hardly be obtained. Therefore, effecting annular illumination will become meaningless in itself.

If conversely, the upper limit of conditional expression (2) is exceeded, the resolution as a spatial image will be improved, but the depth of focus will be reduced. Further, the contrast at the best focus will be greatly reduced, and this is not preferable.

As described above, in the projection exposure apparatus according to the present invention, a depth of focus greater than in the prior-art projection exposure apparatus can be secured and therefore, exposure under a practically higher resolution can be realized. Thereby, more minute patterns than in the prior-art projection exposure apparatus can be transferred onto wafers.

Other objects, features and effects of the present invention will become fully apparent from the following detailed description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic view schematically showing the construction of a first embodiment of the present invention.

FIG. **2** is a plan view showing the construction of an aperture stop.

FIG. **3** shows the opening portion of an aperture stop provided at the pupil position of a projection optical system.

FIG. **4** schematically shows a modification of the first embodiment of the present invention.

FIG. **5** schematically shows the construction of a second embodiment of the present invention.

FIG. **6** shows the construction of a turret in the second embodiment of the present invention.

FIG. **7** schematically shows a modification of the second embodiment of the present invention.

FIG. **8** is a schematic view schematically showing the construction of a third embodiment of the present invention.

FIG. **9** is a schematic view showing a light guide in the third embodiment of the present invention.

FIG. **10** shows a modification of the first embodiment of the present invention.

FIG. **11** shows a modification of the first embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

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

FIG. **1** schematically shows the construction of a first embodiment of the present invention, and the first embodiment of the present invention will hereinafter be described in detail with reference to FIG. **1**.

Light (for example, light of g-line (436 nm), i-line (365 nm) or the like) from a mercury arc lamp **1** is condensed by an elliptical mirror **2** and is converted into a parallel light beam by a collimator lens **4** via a reflecting mirror **3**. Thereafter, when the parallel light beam passes through a fly-eye lens **5** (optical integrator) comprised of an aggregate of a plurality of bar-like lens elements, a plurality of light source images are formed on the exit side thereof corresponding to the number of the bar-like lens elements constituting the fly-eye lens **5**.

An aperture stop **6** having an annular transmitting portion is provided at a location whereat the secondary light source is formed, and here is formed an annular light source.

The aperture stop **6**, as shown in FIG. **2**, is formed by the deposition of light intercepting portions **6**b and **6**c of chromium or like material so that for example, an annular transmitting portion **6**a may be formed on a transparent substrate such as quartz. Alternatively, the aperture stop **6** may be comprised of a circular light intercepting member and a light intercepting member having a circular opening larger than that.

When here, the diameter of the light intercepting member **6**b of the aperture stop **6** (the inner diameter of the annular transmitting portion **6**a) is d_1 and the diameter of the light intercepting member **6**c of the aperture stop **6** (the outer diameter of the annular transmitting portion **6**a) is d_2 and d_1/d_2 is defined as an annular ratio, the annular ratio of the aperture stop **6** is designed within a range of ⅓ to ⅔.

Now, the light from the annular secondary light source formed by the aperture stop **6** is condensed by a condenser lens **8** via a reflecting mirror **7** and superposedly uniformly illuminate a circuit pattern **9**a on a reticle **9** from an oblique direction. Thereupon, the image of the circuit pattern on the reticle **9** is formed on the exposure area of a wafer **11** by a projection optical system **10**. Accordingly, resist applied onto the wafer **11** is sensitized and the image of the circuit pattern on the reticle **9** is transferred thereto.

Thereafter, the projection exposure apparatus drives a stage **12** on which the wafer **11** is placed, and moves the wafer **11** so that the circuit pattern can be transferred to an area discrete from the afore-mentioned exposure area. The illuminated circuit pattern on the reticle **9** is then transferred by the projection optical system **10**. In this manner, the projection exposure apparatus transfers circuit patterns in succession onto the wafer **11**.

An aperture stop **10**a is provided at the position of the pupil (entrance pupil) of the projection optical system **10**, and this aperture stop **10**a is provided conjugately with the aperture stop **6**.

FIG. **3** shows the state of the circular opening portion P of the aperture stop **10**a, and as shown, the image I of the annular secondary light source is formed inside the opening portion A of the aperture stop **10**a, and the annular ratio of the image I of this secondary light source (the inner diameter D_1 of the image of the secondary light source/the outer diameter D_2 of the image of the secondary light source) is equal to the above-mentioned annular ratio of the aperture stop **6**.

When here, the diameter of the opening portion of the aperture stop **10**a is D_3, the ratio (D_2/D_3) of the outer diameter of the image of the secondary light source to the diameter of the opening portion A of the aperture stop **10**a is called a coherence factor, i.e., σ value, and at this time, the image I of the annular secondary light source is formed within the range of the σ value of 0.45 to 0.8, as shown in FIG. **3**.

When as shown in FIG. **1**, the reticle side numerical aperture of the projection optical system **10** determined by a ray R_1 from the most marginal edge of the aperture stop **10**a which is parallel to the optical axis Ax is NA_1 (=sin θ_1) and the numerical aperture of the illuminating optical system (**1**–**8**) determined by a ray R_2 from the most marginal edge (the outermost diameter) of the aperture stop **6** which is parallel to the optical axis Ax is NA_2 (=sin θ_2), the σ value is also defined by the following equation:

$$\sigma = NA_2/NA_1$$

Now, in the process of printing a circuit pattern on the wafer **11**, there are various processes such as a process in which the printing of a minute pattern is required, and a process in which a great depth of focus is required, and the optimum depth of focus and resolution in each of these processes are found.

Therefore, in the present embodiment, the aperture of the aperture stop **10**a is variably designed and the σ value is varied to thereby control the depth of focus and resolution on the wafer **11**.

A desired depth of focus and resolution are first input by means of an input portion **16** such as a keyboard. A control portion **14** determines the σ value on the basis of this input information, and controls a driving portion **15** for varying the aperture of the aperture stop **10**a. The driving portion **15** varies the diameter of the opening portion A of the aperture stop **10**a and changes the σ value.

Also, as shown in FIG. **4**, a mark **9**b such as a bar code including process information, the information of the desired depth of focus and information regarding a minimum line width on the wafer **11** may be provided on the reticle **9**, and a mark detecting portion **13** for detecting this mark **9**b may be provided. In this case, the control portion **14** determines the σ value on the basis of information detected by the mark detecting portion **13**.

As described above, in the present embodiment, annular illumination is effected by the disposition of the aperture stop **6** and therefore, greater improvements in the depth of focus and resolution can be achieved. Further, the σ value is variable and therefore, an optimum illuminating condition conforming to each process can be achieved.

Also, in the embodiments shown in FIGS. **1** and **4**, the aperture stop **6** is fixedly used, but the annular ratio of this aperture stop **6** may be varied. FIG. **5** is a schematic view schematically showing the construction of a second embodiment in which a plurality of aperture stops differing in annular ratio from one another are provided along the circumferential direction of a circular substrate (turret).

In FIG. **5**, for the simplicity of illustration, members functionally similar to those in the first embodiment shown in FIG. **1** are given the same reference characters.

Only the differences of the second embodiment from the first embodiment will hereinafter be described in detail. In the projection exposure apparatus shown in FIG. **5**, a circular substrate **60** provided with a plurality of aperture stops having different annular ratios is provided at a position on the exit side of the fly-eye lens **5** whereat a plurality of light source images are formed. As shown in the plan view of FIG. **6**, a first group of aperture stops (**60**b–**60**c) having different annular ratios within a range of ⅓–⅔ and a second group of aperture stops (**60**f–**60**h) having an outer diameter differing from that of the first group of aperture stops and having different annular ratios within a range of ⅓–⅔ are provided on the transparent circular substrate **60** by the deposition of chromium or the like. Further, a circular aperture stop **60**a having the same diameter as the outer diameter of the first group of aperture stops and a circular aperture stop **60**e having the same diameter as the outer diameter of the second group of aperture stops are provided on the circular substrate **60**.

In the present embodiment, the aperture stops (**60**b–**60**c, **60**f–**60**h) having optimum annular ratios are set on the exit side of the fly-eye lens **5** and the depth of focus and resolution on the wafer **11** are controlled.

Turning back to FIG. **5**, the control of the above-mentioned depth of focus and resolution will hereinafter be described in detail.

Process information and information regarding the required depth of focus and minimum line width are input by the use of the input portion **16** such as a keyboard.

On the basis of such input information, the control portion **14** selects one of the aperture stops (**60**b–**60**c, **60**f–**60**h). The control portion **14** then controls a driving portion **61** for driving the circular substrate **60** so that the selected one of the aperture stops (**60**b–**60**c, **60**f–**60**h) may be positioned on the exit side of the fly-eye lens **5**.

Thereby, the depth of focus and resolution on the wafer **11** can be controlled and therefore, optimum annular illumination under an optimum σ value can be accomplished. Also, of the aperture stops (**60**a, **60**e) having an usual circular opening are set on the exit side of the fly-eye lens **5**, exposure by usual illumination can be accomplished.

Also, as shown in FIG. **7**, a mark **9**b such as a bar code including process information and information regarding the desired depth of focus and minimum line width on the wafer **11** may be provided on the reticle **9** and a mark detecting portion **13** for detecting this mark **9**b may be provided. In such case, the control portion **14** selects one of the aperture stops (**60**b–**60**c, **60**f–**60**h) on the basis of information detected by the mark detecting portion **13**.

A third embodiment of the present invention will now be described with reference to FIGS. **8** and **9**. FIG. **8** is a schematic view schematically showing the construction of the third embodiment of the present invention. For simplicity of illustration, members functionally similar to those in the first embodiment of FIG. **1** are given the same reference characters.

The difference of the third embodiment from the first embodiment is that instead of the aperture stop **6** provided between the fly-eye lens **5** and the reflecting mirror **7**, there are provided a condensing lens **20** and a light guide **21** comprised of a plurality of optical fibers having their entrance sides bundled into a circular shape and having their exit sides bundled into an annular shape, and a number of annular light sources are formed without intercepting a light beam from the fly-eye lens **5**.

In the third embodiment of FIG. **8**, a plurality of light source images are formed on the exit side of the fly-eye lens **5** by the light from the mercury arc lamp **1** through the intermediary of the elliptical mirror **2**, the reflecting mirror **3**, the collimator lens **4** and the fly-eye lens **5** in succession. Since the exit end of the fly-eye lens **5** and the exit end of the light guide **21** are made into a conjugate relation by the condensing lens **20**, an annular secondary light source is formed at the exit end of the light guide **21**.

As shown in FIG. **9**, a circular member **21**a for bundling a plurality of fibers is provided at the entrance end of the light guide **21** and an annular member **21**b for bundling the plurality of fibers into an annular shape is provided at the exit end of the light guide.

The ratio of the inner diameter of the exit end of the light guide **21** to the outer diameter of the exit end of the light guide **21**, i.e., the annular ratio, is designed so as to be ⅓ to ⅔, and as shown in FIG. **3**, an annular light source image of which the σ value is of the order of 0.45 to 0.8 is formed at the position of the aperture stop **10**a of the projection optical system.

By the above-described construction, in the present embodiment, annular illumination can be effected efficiently without intercepting the light from the light source **1** and therefore, not only greater improvements in the depth of focus and resolution can be achieved, but also exposure under a high throughput can be accomplished.

Again in the present embodiment, as described above, means for detecting a mark including various kinds of information on the reticle may be provided and on the basis of the information detected thereby, the optimum diameter of the opening portion of the aperture stop **10**a may be set, and annular illumination under an optimum σ value may be effected.

Further, in the present embodiment, provision may be made of a plurality of light guides differing in annular ratio and outer diameter from one another and design may be made such that in conformity with the required depth of focus and resolution, one of the plurality of light guides is positioned between the condensing lens **20** and the condenser lens **8**. Thereby, the depth of focus and resolution can be controlled without the illumination efficiency being reduced and optimum annular illumination under an optimum σ value can be accomplished.

Of course, an excimer laser (KrF: 248 nm, ArF: 193 nm, etc.) may be used as the light source of the projection exposure apparatus according to the present embodiment.

Also, in the embodiment shown in FIG. **1**, the fly-eye lens **5** is used as the optical integrator, but this is not restrictive. For example, as shown in FIG. **10**, a bar-like optical element **52** may be employed as the optical integrator. This bar-like optical element **52** is constructed of glass formed into a bar-like shape, or is constructed such that the inner surface of a prismatic or cylindrical barrel is a reflecting surface. The parallel light beam from the mercury arc lamp **1** passed via the elliptical mirror **2**, the reflecting mirror **3** and the collimator lens **4** is condensed on the entrance surface of the bar-like optical element **52** by a lens **51** and repeats reflection on the inner surface of this bar-like optical element **52**, thereby emerging from the bar-like optical element **52** with a uniform illumination distribution. This emergent light forms a light source image on the aperture stop **6** by a lens **53** provided on the exit side of the bar-like optical element **52**. Thereby, an annular secondary light source is formed on the aperture stop **6**.

In the embodiment shown in FIG. **11**, a prism member such as a cone lens **54** of which the entrance side surface and the exit side surface are conical surfaces, as shown, for example, in FIG. **11**, may be disposed in the optical path from the collimator lens **4** to the fly-eye lens **5**. Thereby, the light beam entering the fly-eye lens **5** is made into a parallel light beam of which the cross-sectional shape is annular, and an annular secondary light source is formed on the exit surface of the fly-eye lens **5**. Thus, an annular secondary light source can be provided without involving a reduction in the efficiency of the quantity of light.

In the embodiment shown in FIG. **11**, the cone lens **54** may be divided by a plane perpendicular to the optical axis. In other words, the cone lens **54** may be formed or replaced by two optical elements, one being an optical element whose light incident side (end) has a conically recessed surface and whose light exit side (end) has a flat plane surface, and the other being an optical element which has a flat plane end surface at a light incident side and a conically projected end surface at a light exit side, and both of these elements being arranged between the collimator lens **4** and the fly-eye lens **5**. Such an arrangement may form an annular secondary light source at a light exit plane of the fly-eye lens **5**. By changing a distance along the optical axis between those two optical elements, an annular ratio of the secondary light source formed on the exit plane of the fly-eye lens can be changed.

Further, in the embodiment shown in FIG. **11**, design may be made such that the inner diameter and outer diameter of the aperture stop **6** are variable, and this aperture stop **6** may be disposed at any location which is conjugate with the position at which the secondary light source is formed. For example, it is also conceivable to dispose a stop of which the diameter of the opening portion is variable on the exit surface side of the fly-eye lens **5**, dispose a stop of which the diameter of the light intercepting portion is variable at a location conjugate with the exit surface of the fly-eye lens, and vary the annular ratio and σ value of the annular secondary light source.

In the above described embodiments, the aperture stop may be formed by a transparent type liquid crystal display device, an electrochromic device or the like.

What is claimed is:

1. A projection exposure apparatus including:

illuminating optical means for illuminating a projection negative; and

projection optical means for projection-exposing said projection negative illuminated by said illuminating optical means onto a substrate;

said illuminating optical means including light source means for supplying exposure light, annular light source forming means for forming an annular secondary light source, which has a plurality of light source images, by the light from said light source means, and condenser means for condensing light from said annular light source forming means on said projection negative;

said apparatus satisfying the following condition:

$$\frac{1}{3} \leqq d_1/d_2 \leqq \frac{2}{3},$$

where d_1 is the inner diameter of said annular secondary light source, and d_2 is the outer diameter of said annular secondary light source;

said apparatus also satisfying the following condition:

$$0.45 \leqq NA_2/NA_1 \leqq 0.8,$$

where NA_1 is the numerical aperture of said projection optical means, and NA_2 is the numerical aperture of said illuminating optical means determined by the outer diameter of said annular secondary light source.

2. A projection exposure apparatus according to claim **1**, wherein said annular light source forming means includes:

an optical integrator; and

stop means disposed in the optical path of light emerging from said optical integrator and having an annular opening portion.

3. A projection exposure apparatus according to claim **2**, wherein said optical integrator is comprised of a plurality of lens elements.

4. A projection exposure apparatus according to claim **2**, wherein said optical integrator includes a bar-like optical element.

5. A projection exposure apparatus according to claim **2**, wherein said stop means has a plurality of opening portions differing in the ratio of the inner diameter of said annular opening portion to the outer diameter of said annular opening portion from one another, and one of said plurality of opening portions of said stop means is disposed in said optical path.

6. A projection exposure apparatus according to claim **5**, wherein said stop means includes a circular opening portion.

7. A projection exposure apparatus according to claim **5**, further including:

driving means for disposing one of said plurality of opening portions in said optical path;

input means for inputting information regarding various conditions during exposure; and

control means for controlling said driving means on the basis of the input information from said input means.

8. A projection exposure apparatus according to claim **7**, wherein said input means includes detecting means for detecting a mark on said projection negative on which the information regarding the various conditions during exposure is recorded.

9. A projection exposure apparatus according to claim **1**, wherein said projection optical means includes an aperture stop of which the diameter of the opening is variable, and said projection exposure apparatus further includes:

driving means for varying said diameter of the opening of said aperture stop;

input means for inputting information regarding various conditions during exposure; and

control means for controlling said driving means on the basis of the input information from said input means.

10. A projection exposure apparatus according to claim **1**, wherein said annular light source forming means includes light guide means for transmitting said exposure light.

11. A projection exposure apparatus according to claim **10**, wherein said light guide means is constructed such that the entrance side cross-sectional shape of said light guide means is circular and the exit side cross-sectional shape of said light guide means is annular.

12. A projection exposure apparatus including:

illumination optical means for illuminating a projection negative; and

projection optical means for projection-exposing said projection negative illuminated by said illumination optical means onto a substrate;

said illumination optical means including light source means for supplying exposure light, means for forming a secondary light source, which has a plurality of light source images, by the light from said light source means, means including annular ratio changing means for converting said secondary light source into an annular secondary light source and changing a ratio between an inner diameter and outer diameter of said annular secondary light source, and condenser means for condensing light from said annular secondary light source onto said projection negative,

said apparatus satisfying the following condition:

$$\tfrac{1}{3} \leqq d_1/d_2 \leqq \tfrac{2}{3}$$

where d_1 is the inner diameter of said annular secondary light source, and d_2 is the outer diameter of said annular secondary light source, and said apparatus satisfying the following condition:

$$0.45 \leqq NA_2/NA_1 \leqq 0.8$$

where NA_1 is the numerical aperture of said projection optical means, and NA_2 is the numerical aperture of said illumination optical means determined by the outer diameter of said annular secondary light source.

13. A projection exposure apparatus according to claim **12**, wherein said means for forming said secondary light source has an optical integrator.

14. A projection exposure apparatus according to claim **13**, wherein said annular ratio changing means includes stop means disposed in an optical path of light flux emergent from said optical integrator and having an annular opening portion.

15. A projection exposure apparatus according to claim **14**, wherein said stop means includes a plurality of opening portions differing from one another in a ratio of inner diameter of said annular opening portion to outer diameter of said annular opening portion, and one of said plurality of opening portions of said stop means is disposed in the optical path of said illumination optical means.

16. A projection exposure apparatus according to claim **15**, wherein said stop means includes a circular opening portion.

17. A projection exposure apparatus according to claim **15**, further including:

driving means for disposing one of said plurality of opening portions in said optical path;

input means for inputting information regarding various conditions during exposure; and

control means for controlling said driving means on the basis of the input information from said input means.

18. A projection exposure apparatus according to claim **12**, further including:

input means for inputting information regarding various conditions during exposure; and

control means for controlling said annular ratio changing means on the basis of the input information from said input means.

19. A projection exposure apparatus according to claim **18**, wherein said annular ratio changing means includes a plurality of opening portions of which a ratio between an inner diameter and an outer diameter is different from one another, and one of said plurality of opening portions is disposed in an optical path of said illumination optical means.

20. A projection exposure apparatus according to claim **18**, wherein said annular ratio changing means is disposed in an optical path of said illumination optical means and includes a movable stop for changing the ratio between the inner diameter and outer diameter.

21. A projection exposure apparatus comprising: an illuminating optical system; and

a projection optical system;

said illumination optical system including a light source, an optical integrator and a condenser optical system;

light from said light source passing through said optical integrator, said condenser optical system, a projection negative and said projection optical system, and onto a substrate;

said optical integrator forming a plurality of annular light source images; and the following conditions being satisfied:

$$1/3 \leqq d_1/d_2 \leqq 2/3$$

$$0.45 \leqq NA_2/NA_1 \leqq 0.8$$

where d_1 is an inner diameter of said plurality of annular light source images, d_2 is an outer diameter of said plurality of annular light source images, NA_1 is the numerical aperture of said projection optical system at a side of said projection negative and NA_2 is the numerical aperture of said condenser optical system at an exit side determined by the outer diameter of said plurality of annular light source images.

22. A projection exposure apparatus including:

an illumination optical system; and

a projection optical system;

said illumination optical system including a light source, an optical integrator, an annular stop and a condenser optical system;

light from said light source passing through said optical integrator, said condenser optical system, a projection negative and said projection optical system and onto a substrate;

said annular stop being provided at a position where a plurality of images are formed by said illumination optical system;

said apparatus satisfying the following conditions:

$$1/3 \leqq d_1/d_2 \leqq 2/3$$

$$0.45 \leqq NA_2/NA_1 \leqq 0.8$$

where d_1 is an inner diameter of an opening of said annular stop, d_2 is an outer diameter of the opening of said annular stop, NA_1 is the numerical aperture of said projection optical system at a side of said projection negative and NA_2 is the numerical aperture of said condenser optical system at an exit side determined by the outer diameter of the opening of said annular stop.

23. A projection exposure apparatus comprising:

an illuminating optical system; and

a projection optical system;

said illuminating optical system including a light source, an optical integrator, an annular stop and a condenser optical system;

light from said light source passing through said optical integrator, said condenser optical system, a projection negative and said projection optical system and onto a substrate;

said illuminating optical system forming a plurality of annular light source images satisfying the following condition:

$$1/3 \leqq d_1/d_2 \leqq 2/3$$

where d_1 is an inner diameter of said plurality of annular light source images and d_2 is an outer diameter of said plurality of annular light source images; and

said projection exposure apparatus satisfying the following condition:

$$0.45 \leqq NA_2/NA_1 \leqq 0.8,$$

where NA_1 is the numerical aperture of said projection optical system at a side of said projection negative, and NA_2 is the numerical aperture of said condenser optical system at an exit side determined by an outer diameter of an opening of said annular stop.

24. A projection exposure apparatus comprising:

an illuminating optical system; and

a projection optical system;

said illuminating optical system including a light source, an optical integrator and a condenser optical system;

light from said light source passing through said optical integrator, said condenser optical system, a projection negative and said projection optical system and onto a substrate;

said illuminating optical system forming a plurality of annular light source images satisfying the following condition:

$$1/3 \leqq d_1/d_2 \leqq 2/3,$$

where d_1 is an inner diameter of said plurality of annular light source images, d_2 is an outer diameter of said plurality of annular light source images;

the ratio between the inner diameter and the outer diameter of said annular light source images being variable within the range of said condition;

said projection exposure apparatus satisfying the following condition:

$$0.45 \leqq NA_2/NA_1 \leqq 0.8,$$

where NA_1 is the numerical aperture of said projection optical system at a side of said projection negative, and NA_2 is the numerical aperture of said condenser optical system at an exit side determined by the outer diameter of said plurality of annular light source images.

25. A projection exposure apparatus comprising:

an illuminating optical system; and

a projection optical system;

said illuminating optical system including a light source, an optical integrator, a first annular stop, a second annular stop and a condenser optical system;

light from said light source passing through said optical integrator, said condenser optical system, a projection negative and said projection optical system and onto a substrate;

said first and second annular stops satisfying the following condition:

$$1/3 \leqq d_1/d_2 \leqq 2/3,$$

where d_1 is an inner diameter of an opening of said annular stops and d_2 is an outer diameter of an opening of said annular stops;

said first and second annular stops being selectively disposed in a position where a plurality of light source images are formed by said illuminating optical system; and

said projection exposure apparatus satisfying the following condition:

$$0.45 \leqq NA_2/NA_1 \leqq 0.8,$$

where NA_1 is the numerical aperture of said projection optical system at a side of said projection negative, and NA_2 is the numerical aperture of said condenser optical system at an exit side determined by the outer diameter of said plurality of annular light source images.

26. A projection exposure apparatus comprising:

an illumination optical system in which an optical system is disposed on an optical path to form an annular secondary light source with light emitted by a first light source, said optical system changing an annular ratio of an inner diameter to an outer diameter with respect to the annular secondary light source; and

a projection optical system disposed in an optical path between the mask and a substrate so as to project an image of the mask onto the substrate;

said illumination optical system satisfying the following condition:

$$\tfrac{1}{3} \leqq d_1/d_2 \leqq \tfrac{2}{3}$$

wherein d_1 is the inner diameter of the annular secondary light source and d_2 is the outer diameter of the annular secondary light source.

27. An apparatus according to claim 26, wherein said optical system includes an optical integrator and an optical element having a conical surface, disposed between said first light source and the optical integrator.

28. An apparatus according to claim 27, wherein said optical integrator includes a fly-eye type integrator or an internal reflection type integrator.

29. An apparatus according to claim 26, wherein said optical system satisfies the following condition:

$$0.45 \leqq NA_2/NA_1 \leqq 0.8$$

wherein NA_1 is the numerical aperture of said projection optical system, and NA_2 is the numerical aperture of said illumination optical system determined by the outer diameter of said annular secondary light source.

30. An apparatus according to claim 26, wherein said optical system comprises a plurality of annular stops having annular ratios that are different from each other so as to set one of said plurality of annular stops in an optical path selectively.

31. An apparatus according to claim 26, wherein said optical system comprises a first optical element with a first conical surface, a second optical element with a second conical surface and a variable distance between said first optical element and said second optical element so as to change an annular ratio with respect to the annular secondary light source.

32. An apparatus according to claim 31, wherein said optical system further comprises an optical integrator disposed in an optical path between said second optical element and the mask.

33. A projection exposure apparatus comprising:

an illumination optical system disposed on an optical path of light emitted by a light source so as to illuminate a mask, the illumination optical system including an optical system disposed in an optical path between the light source and the mask so as to form a variable annular illumination source, said optical system changing an annular ratio of the variable annular illumination source; and

a projection optical system disposed in an optical path between the mask and a substrate so as to project an image of the mask onto the substrate;

said projection exposure apparatus satisfying the following condition:

$$0.45 \leqq NA_2/NA_1 \leqq 0.8$$

wherein NA_1 is the numerical aperture of said projection optical system, and NA_2 is the numerical aperture of said illumination optical system determined by the outer diameter of said variable annular illumination source.

34. An apparatus according to claim 33, wherein said illumination optical system includes an optical integrator and a stop disposed adjacent to the optical integrator to form said annular illumination source.

35. An apparatus according to claim 33, wherein said optical system changes the annular ratio of said annular illumination source in accordance with a pattern on said mask.

36. An apparatus according to claim 35, wherein said optical system includes a plurality of annular stops having annular ratios that are different from each other, one of the plurality of annular stops selected in accordance with said pattern being disposed on said optical path.

37. An apparatus according to claim 33, wherein said optical system comprises a first optical element with a first conical surface, a second optical element with a second conical surface and a variable distance between said first optical element and said second optical element so as to change an annular ratio with respect to the variable annular illumination source.

38. An apparatus according to claim 37, wherein said optical system further comprises an optical integrator disposed in an optical path between said second optical element and the mask.

39. A projection exposure apparatus comprising:

an illumination optical system disposed in an optical path of light emitted by a light source so as to illuminate a mask, the illumination optical system including an optical system disposed in an optical path between the light source and the mask so as to form an annular illumination source, said optical system changing an annular ratio of the annular illumination source in accordance with a pattern formed on the mask; and

a projection optical system disposed in an optical path between the mask and a substrate so as to project an image of the mask onto the substrate, said projection optical system including a pupil defining unit disposed within the projection optical system so as to define a pupil of the projection optical system;

wherein the pupil defining unit comprises a variable aperture stop.

40. An apparatus according to claim 39, wherein said projection optical system has a numerical aperture not less than 0.4 at a side of the substrate.

41. An apparatus according to claim 39, wherein said illumination optical system satisfies the following condition:

$$\tfrac{1}{3} \leqq d_1/d_2$$

wherein d_1 is the inner diameter of the annular secondary light source and d_2 is the outer diameter of the annular secondary light source.

42. An apparatus according to claim 41, wherein said projection exposure apparatus satisfies the following condition:

$$0.45 \leqq NA_2/NA_1$$

wherein NA_1 is a numerical aperture of said projection optical system, and NA_2 is a numerical aperture of said illumination optical system determined by the outer diameter of said variable annular illumination source.

43. An apparatus according to claim 41, wherein said optical system comprises an optical integrator and an aperture stop unit disposed in an optical path between said optical integrator and the mask, the aperture stop unit includes a circular opening and an annular opening so as to selectively form one of a circular illumination source and the annular illumination source.

44. An apparatus according to claim 41, wherein said optical system changes the annular ratio with respect to the annular illumination source under a high illumination efficiency.

45. An apparatus according to claim 44, wherein said optical system comprises a first optical element with a first conical surface that is disposed in an optical path between the light source and the mask, a second optical element with a second conical surface that is disposed in the optical path between said first optical element and the mask, and a variable distance between said first optical element and said second optical element so as to change an annular ratio with respect to the annular illumination source.

46. An apparatus according to claim 45, wherein said optical system further comprises an optical integrator disposed in an optical path between said second optical element and the mask.

47. A projection exposure apparatus comprising:

an illumination optical system disposed in an optical path between a light source and a mask so as to illuminate the mask;

a projection optical system disposed in an optical path between the mask and a substrate so as to project an image of the mask onto the substrate; and

an optical system disposed within the illumination optical system so as to form one of a circular secondary light source and an annular secondary light source selectively based on light from the light source, the optical system changing a size of the circular secondary light source and changing an annular ratio of the annular secondary light source.

48. An apparatus according to claim 47, wherein said projection exposure apparatus satisfies the following condition:

$$0.45 \leqq NA_2/NA_1$$

wherein NA_1 is a numerical aperture of said projection optical system, and NA_2 is a numerical aperture of said illumination optical system determined by the outer diameter of said variable annular illumination source.

49. An apparatus according to claim 48, wherein said optical system comprises an optical integrator and an aperture stop disposed in an optical path between the optical integrator and the mask, the aperture stop unit includes a circular opening and an annular opening so as to selectively form one of the circular secondary light source and the annular secondary light source.

50. An apparatus according to claim 48, wherein said optical system comprises a first optical element with a first conical surface that is disposed in an optical path between the light source and the mask, a second optical element with a second conical surface that is disposed in the optical path between said first optical element and the mask, and a variable distance between said first optical element and said second optical element so as to change the annular ratio with respect to the annular secondary light source.

51. An apparatus according to claim 50, wherein said illumination optical system satisfies the following condition:

$$1/3 \leqq d_1/d_2$$

wherein d_1 is the inner diameter of the annular secondary light source and d_2 is the outer diameter of the annular secondary light source.

52. An apparatus according to claim 48, wherein said illumination optical system satisfies the following condition:

$$1/3 \leqq d_1/d_2$$

wherein d_1 is the inner diameter of the annular secondary light source and d_2 is the outer diameter of the annular secondary light source.

53. A projection exposure apparatus comprising:

an illumination optical system in which an internal reflection type integrator is disposed on an optical axis to illuminate a mask with light from a light source passing through the internal reflection type integrator; and

a projection optical system, disposed in an optical path between the mask and a substrate, through which light from the mask passes, the projection optical system including a pupil defining unit disposed within the projection optical system so as to define a pupil of the projection optical system;

said illumination optical system including an optical device disposed on the optical axis to form a light intensity distribution having a substantially annular shape on a pupil plane of the illumination optical system, the optical device being capable of changing at least one of the annular ratio, the outer diameter, and the inner diameter of the light intensity distribution in accordance with a pattern on the mask.

54. An apparatus according to claim 53, wherein said optical device comprises a plurality of annular stops having annular ratios that are different from each other so as to set one of said plurality of annular stops in an optical path selectively.

55. An apparatus according to claim 53, wherein said optical device changes the annular ratio with respect to the light intensity distribution under a high illumination efficiency.

56. An apparatus according to claim 55, wherein said optical device comprises a first optical element with a first conical surface, a second optical element with a second conical surface and a variable distance between said first optical element and said second optical element so as to change the annular ratio.

57. An apparatus according to claim 56, wherein said optical device further comprises an optical integrator disposed between said second optical element and the mask.

58. An apparatus according to claim 53, wherein said illumination optical system satisfies the following condition:

$$1/3 \leqq d_1/d_2$$

wherein d_1 is the inner diameter of the annular secondary light source and d_2 is the outer diameter of the annular secondary light source.

59. An apparatus according to claim 58, wherein said projection exposure apparatus satisfies the following condition:

$$0.45 \leqq NA_2/NA_1$$

wherein NA_1 is a numerical aperture of said projection optical system, and NA_2 is a numerical aperture of said illumination optical system determined by the outer diameter of said variable annular illumination source.

60. An apparatus according to claim 58, wherein said optical device comprises a first optical element with a first *conical surface, a second optical element with a second conical surface and a variable distance between said first optical element and said second optical element so as to change the annular ratio.*

61. An apparatus according to claim 60, wherein said projection exposure apparatus satisfies the following condition:

$$0.45 \leqq NA_2/NA_1$$

wherein NA_1 is a numerical aperture of said projection optical system, and NA_2 is a numerical aperture of said illumination optical system determined by the outer diameter of said variable annular illumination source.

62. A projection exposure apparatus comprising:

an illumination optical system that illuminates a mask and comprising a light source including an excimer laser, and an optical system disposed in an optical path formed by the light source so as to form an annular secondary light source having a light intensity distribution with a substantially annular shape on a pupil of the illumination optical system and an deflection member disposed in an optical path between said light source and said optical system; and

a projection optical system disposed in an optical path between the mask and a substrate so as to project an image of the mask onto the substrate;

wherein said optical system changes an annular ratio with respect to the light intensity distribution.

63. An apparatus according to claim 62, wherein said projection exposure apparatus satisfies the following condition:

$$0.45 \leqq NA_2/NA_1$$

wherein NA_1 is a numerical aperture of said projection optical system, and NA_2 is a numerical aperture of said illumination optical system determined by the outer diameter of said variable annular illumination source.

64. An apparatus according to claim 63, further comprising:

an optical integrator disposed in an optical path between said optical system and the mask, said optical integrator including a fly-eye type integrator or an internal reflection type integrator.

65. An apparatus according to claim 63, further comprising a pupil changing unit disposed within said projection optical system so as to define a pupil of said projection optical system and change a numerical aperture of said projection optical system.

66. An apparatus according to claim 62, wherein said optical system includes a first optical element with a first conical surface that is disposed in an optical path between the light source and the mask, a second optical element with a second conical surface that is disposed in the optical path between said first optical element and the mask, and a variable distance between said first optical element and said second optical element so as to change the annular ratio with respect to the light intensity distribution.

67. An apparatus according to claim 66, further comprising a pupil changing unit disposed within said projection optical system so as to define a pupil of said projection optical system and change a numerical aperture of said projection optical system.

68. An apparatus according to claim 66, wherein said optical system further comprises an optical integrator disposed in an optical path between said second optical element and the mask.

69. An apparatus according to claim 62, wherein said illumination optical system satisfies the following condition:

$$\tfrac{1}{3} \leqq d_1/d_2 \leqq \tfrac{2}{3}$$

where d_1 is the inner diameter of the annular secondary light source and d_2 is the outer diameter of the annular secondary light source.

70. An apparatus according to claim 62, wherein said optical system changes the annular ratio with respect to the annular secondary light source under a high illumination efficiency.

71. An apparatus according to claim 70, wherein said optical system includes a first optical element with a first conical surface that is disposed in an optical path between the light source and the mask, a second optical element with a second conical surface that is disposed in the optical path between said first optical element and the mask, and a variable distance between said first optical element and said second optical element so as to change the annular ratio with respect to the light intensity distribution.

72. An apparatus according to claim 71, wherein said optical system further comprises an optical integrator disposed in an optical path between said second optical element and the mask.

73. An apparatus according to claim 65, wherein said pupil defining unit comprises an aperture stop unit changing the pupil of said projection optical system.

74. An apparatus according to claim 73, wherein said aperture stop unit comprises a variable aperture stop.

75. A projection exposure apparatus comprising:

an illumination optical system disposed in an optical path of light emitted by a light source so as to illuminate a mask, said illumination optical system including an optical system disposed in an optical path between the light source and the mask so as to form a variable annular illumination source, said optical system changing an annular ratio with respect to the annular illumination source; and

a projection optical system disposed in an optical path between the mask and a substrate so as to project an image of the mask onto the substrate, said projection optical system including a pupil defining unit disposed within said projection optical system so as to define a pupil of said projection optical system;

said projection exposure apparatus satisfying the following condition:

$$0.45 \leqq NA_2/NA_1$$

wherein NA_1 is a numerical aperture of said projection optical system, and NA_2 is a numerical aperture of said illumination optical system determined by the outer diameter of said variable annular illumination source.

76. An apparatus according to claim 75, wherein said optical system changes the annular ratio with respect to the annular illumination source under a high illumination efficiency.

77. An apparatus according to claim 76, wherein said optical system comprises a first optical element with a first conical surface that is disposed in an optical path between the light source and the mask, a second optical element with a second conical surface that is disposed in the optical path between said first optical element and the mask, and a variable distance between said first optical element and said second optical element so as to change the annular ratio with respect to the annular illumination source.

78. An apparatus according to claim 77, wherein said optical system further comprises an optical integrator disposed in an optical path between said second optical element and the mask.

79. An apparatus according to claim 76, wherein said pupil defining unit comprises an aperture stop unit changing the pupil of said projection optical system.

80. An apparatus according to claim 79, wherein said aperture stop unit comprises a variable aperture stop.

81. An apparatus according to claim 76, wherein said projection optical system has a numerical aperture not less than 0.4 at a side of the substrate.

82. An apparatus according to claim 75, wherein said illumination optical system satisfies the following condition:

$$\frac{1}{3} \leqq d_1/d_2$$

wherein d_1 is the inner diameter of the annular secondary light source and d_2 is the outer diameter of the annular secondary light source.

* * * * *