

DESCRIPTION

METHOD AND DEVICE FOR FORMING A CRYSTALLIZED FILM

Technical Field

[0001]

The present invention relates to a method and device for forming a crystallized film with laser light.

Background Art

[0002]

A device described in Patent Document 1 is known as a conventional device of this type. It is an illumination device for a semiconductor exposure apparatus that is capable of uniformly illuminating an illumination target surface by reducing Moire fringes on a mask surface or a wafer surface from an excimer laser, namely, coherent laser light, which is employed because of the fact that the resolution line width of a transferred circuit pattern is in proportion to a wavelength of a light source.

[0003]

That is, the illumination device is, as shown in FIGS. 4 and 5, characterized in that, when a flux of light from a laser light source 71 is split into plural light fluxes B1, B2 ... Bn by light flux splitting means 72, which includes optical members 79 and 80 composed of plural beam splitters, to illuminate an illumination target surface with the plural light fluxes B1, B2 ... Bn, an optical

path difference is created by placing diverting means R1 and R2, which are composed of reflecting mirrors, between the optical members 79 and 80 in a manner in which a distance equal to or larger than $l_1 - l_2$ is put between every two adjacent light fluxes out of the plural light fluxes B1, B2 ... Bn through the diverting means R1 and R2. The optical path difference $l_1 + l_2$ can be set longer than the coherent length of the light source 71.

[0004]

Reference numeral 73 denotes an afocal lens (a first array lens) which reduces the diameter of each of plural incident light fluxes that have exited the light flux splitting means 72. Reference numeral 75 denotes a fly's eye lens (a second array lens) which is composed of plural minute lenses and forms an incoherent secondary light source plane 76 by making the plural light fluxes that have exited the afocal lens 73 converge on focal planes of the minute lenses. Reference numeral 77 denotes a condenser lens for illuminating an illumination target surface R on which a circuit pattern such as a reticle is formed with the light fluxes that have traveled from the secondary light source plane 76. Reference numeral 78 denotes a projection optical system which projects the circuit pattern drawn on the illumination target surface R onto a wafer surface W.

[0005]

Another conventional device is described in Patent Document

2. This device, as shown in FIG. 6, includes a laser light source 60, a light source image forming member (64), which forms plural light source images 61' from a light flux supplied by the laser light source 60, and a condenser optical system (65), which collects light from the plural light source images 61' to illuminate an illumination target object 66 in an overlapping manner, and is characterized in that an optical path difference creating member 63 and a transmittance correcting member 67 are placed along optical paths between the laser light source 60 and the plural light source images 61', the optical path difference creating means 63 preventing Moire fringes from being formed on a surface of the illumination target object 66 by creating an optical path difference between plural optical paths that correspond to the plural light source images 61', and the transmittance correcting member 67 avoiding uneven illumination of the surface of the illumination target object 66 by correcting transmittance irregularities which are created between the plural light paths by the optical path difference creating member 63.

[0006]

A bundle of rays exiting the laser light source 60, which is shown as a point source 61 and a positive lens 62, passes through the optical path difference creating member 63, which has plural level differences, and then enters a lenticular lens 64 (array lens), which has as many lens blocks as the number of level differences

of the optical path difference creating member 63, to form as many light source images 61' as the number of level differences of the optical path difference creating member 63 in the vicinity of the exit surface of the lenticular lens 64. Light fluxes that have traveled from the plural light source images 61' illuminate a surface of the illumination target object 66 in an overlapping manner via the condenser lens 65.

Patent Document 1: JP 62-25483 B

Patent Document 2: JP 7-21583 B

Disclosure of the Invention

Problem to be solved by the Invention

[0007]

However, the methods and devices for forming a crystallized film with laser light that are described in Patent Documents 1 and 2 have the following technical problems.

[0008]

First, in the optical system of Patent Document 1 where the light splitting means, which is composed of the afocal lens 73, and the optical path difference creating member, which is composed of the beam splitters and the reflecting mirrors 79, 80, R1, and R2, are placed sequentially in front of the fly's eye lens 75 (the second array lens), light beams incident on the fly's array lens 75 (the second array lens) split by the beam splitter (79) are turned

into Gaussian beams. These Gaussian beams form a mountain, and overlapping such Gaussian beams on an illumination target surface does not yield illumination of high uniformity.

[0009]

In addition, in Patent Document 1 where an optical path difference is created between the plural light fluxes B1, B2 ... Bn by putting a distance equal to or larger than $l_1 - l_2$ between every two adjacent light fluxes, and the optical path difference $l_1 + l_2$ can be set longer than the coherent length of the light source 1, the diverting means R1 and R2 ... placed between the optical members 79 and 80, instead of an optical path difference creating member, constitute means for creating an optical path difference, and creates an optical path difference between the plural light fluxes B1, B2 ... Bn via the diverting means R1 and R2

[0010]

This not only makes the means for creating an optical path difference large in size, but also raises a technical problem in that it is difficult to adjust the positions and angles of the mirrors constituting the optical members 79 and 80 and the diverting means R1 and R2 ..., and it is therefore impossible to obtain excellent illumination.

[0011]

On the other hand, in Patent Document 2, the optical path

difference creating member 63 is placed between the laser light source 60 and the lenticular lens 64 (array lens), and light exiting the optical path difference creating member 63 with plural level differences enters the lenticular lens 64 (array lens) having as many lens blocks as the number of the level differences of the optical path difference creating member 63 to form as many light source images 61' as the number of the level differences in the vicinity of the exit surface of the lenticular lens 64.

[0012]

Since the lenticular lens 64 (array lens) is placed on a downstream side of the optical path difference creating means 63, the laser light source 60 emits laser light as a bundle of rays having a divergence angle θ , and the laser light, after exiting one block portion of the single optical path difference creating member 63, is incident on plural lens portions of the lenticular lens 64 (array lens). This means that laser light that has exited plural level differences of the optical path difference creating member 63 is incident on one lens portion of the lenticular lens 64 (array lens).

Accordingly, interference is unavoidable when an image is formed on the illumination target object 66.

[0013]

If the optical path difference creating member 63 is constructed from a group of individual block portions and laser

light is transmitted through this optical path difference creating member 63 before being reduced into plural split rays by the lenticular lens 64 (array lens), laser light as a bundle of parallel rays having an inevitable divergence angle θ generates a large amount of reflection light on inner side faces of each block portion of the optical path difference creating member 63, and thus makes it impossible to obtain illumination of high uniformity. This is fomented by the fact that the optical path difference creating member 63 has a block portion width that is equal to the laser light incident width.

[0014]

Furthermore, since the laser light incident surface of each lens portion of the lenticular lens 64 (array lens) is planar in the optical system of Patent Document 2, laser light having a divergence angle θ is reflected a lot at inner side faces of each lens portion after being incident on the lens portion.

[0015]

A thin film-like material crystallized by uneven laser irradiation according to these methods and devices cannot avoid irregularities in size of crystal grains.

Means for solving the Problem

[0016]

The present invention has been made in view of those technical

problems of prior art, in particular, the present invention solves the technical problem caused by laser light that is emitted from a laser light source as a bundle of rays having a given divergence angle. The structure thereof is as follows.

The invention of Claim 1 provides a method of forming a crystallized film, characterized by including: sequentially arranging a first array lens 2, a second array lens 3, an optical path difference creating member 7, a condenser lens 5, and an illumination target surface 6 in a side view with respect to a laser light source A which emits laser light 1 as a bundle of rays having a divergence angle θ , the first array lens 2 being composed of plural cylindrical lenses 2a, the second array lens 3 being composed of plural cylindrical lenses 3a, the optical path difference creating member 7 having plural block portions 7a that create an optical path difference; transmitting the laser light 1 emitting from the laser light source A through the first array lens 2 to obtain as many split rays 9 that have been reduced as the number of the adjoining cylindrical lenses 2a of the first array lens 2, the cylindrical lenses 2a each having a width d; transmitting the split rays 9 separately through the corresponding cylindrical lenses 3a of the second array lens 3 to obtain reduced split rays 10 which are each narrower than the width d of the cylindrical lenses 2a of the first array lens 2; transmitting the reduced split rays 10 separately through the corresponding block portions 7a of the

optical path difference creating member 7 while reducing reflection on the side of splitting surfaces, to create an optical path difference between the reduced split rays 10 in a manner in which the coherence is adjusted; and overlapping the reduced split rays 10 through the condenser lens 5 to illuminate the illumination target surface 6.

The invention of Claim 2 provides the method of forming a crystallized film according to Claim 1, characterized in that a difference (ΔL) in length between the block portions 7a of the optical path difference creating member 7 is set such that an optical path difference larger than a coherent length is created between the reduced split rays 10.

The invention of Claim 3 provides the method of forming a crystallized film according to Claim 1 or 2, characterized in that a width d of each of the block portions 7a of the optical path difference creating member 7 is equal to or smaller than the width d of each of the cylindrical lenses 2a of the first array lens 2.

The invention of Claim 4 provides the method of forming a crystallized film according to Claim 1, 2, or 3, characterized in that an incident surface 11 of the cylindrical lenses 2a of the first array lens 2 on which the laser light 1 is incident has a positive convex curve.

The invention of Claim 5 provides the method of forming a crystallized film according to Claim 1, 2, 3, or 4, characterized

in that the first array lens 2 and the illumination target surface 6 are in a conjugation relation.

The invention of Claim 6 provides a crystallized film forming device for illuminating an illumination target surface 6 with shaped laser light 1 emitted from a laser light source A as a bundle of rays that have a divergence angle θ , characterized by including: splitting/reducing means (2, 3) for splitting and reducing the laser light 1 into plural split rays 9 in one side view of the laser light source A, and then turning the split rays 9 into individual bundles of reduced rays to obtain reduced split rays 10; an optical path difference creating member 7 having block portions 7a, through which the reduced split rays 10 are individually transmitted while reducing reflection on the side of splitting surfaces, to thereby create an optical path difference between the reduced split rays 10 in a manner in which the coherence is adjusted; and a condenser lens 5 for collecting the reduced split rays 10 that have been transmitted through the optical path difference creating member 7, and characterized in that the illumination target surface 6 is illuminated with laser light overlapped through the condenser lens 5.

Transmitting the reduced split rays 10 individually through the corresponding block portions 7a of the optical path difference creating member 7 while reducing reflection on the splitting surface side and creating an optical path difference between the reduced

split rays 10 so that the coherence is adjusted include a case of rendering the reduced split rays 10 incoherent with one another and a case of making the reduced split rays 10 interfere one another to a given degree through adjustment.

Effect of the Invention

[0017]

As understood from the above description, according to a method and device for forming a crystallized film according to the present invention present the following effects can be obtained.

In an invention according to Claims 1 and 6, laser light emitted from a laser light source as a bundle of rays having a divergence angle θ is split and reduced into plural split rays in one side view of the laser light source, the split rays are turned into individual bundles of reduced rays to obtain reduced split rays, and the reduced split rays are individually transmitted through block portions of an optical path difference creating member while reducing reflection on the splitting surface side.

[0018]

The block portions of the optical path difference creating member create an optical path difference between the reduced split rays so that the coherence is adjusted. The reduced split rays that have transmitted through the optical path difference creating member are collected by a condenser lens, and the laser light transmitted through the condenser lens irradiates an illumination

target surface in an overlapping manner.

[0019]

This makes it possible to obtain a uniform laser by reducing reflection on side faces of a simple optical path difference creating member that is easy to adjust a position and angle and that is capable of providing an excellent image when laser light enters the optical path difference creating member as individual reduced split rays having an optical path difference.

[0020]

Only one reduced split ray is transmitted through each block portion of the optical path difference creating member, which also contributes to the uniformity of obtained laser light.

[0021]

Interference among laser beams is thus controlled and crystal grains of uniform size are obtained by irradiating a thin film-like material with a uniform laser to be crystallized. In addition, the sequential arrangement of the means for splitting and reducing laser light, the optical path difference creating member, the condenser lens, and the illumination target surface makes it possible to control interference among laser beams by setting the length of the optical path difference creating means arbitrarily without affecting the beam shape on the illumination target surface.

[0022]

In an invention according to Claim 2, block portions of an

optical path difference creating member are set to different lengths so that an optical path difference exceeding the coherent length is created between reduced split rays, and therefore the reduced split rays irradiating an illumination target surface are well prevented from interfering one another.

[0023]

In an invention according to Claim 3, a block portion width a of an optical path difference creating member is equal to or smaller than a cylindrical lens width d of a first array lens. Therefore, the same effects that are presented by the invention of Claim 1 are obtained by transmitting reduced split rays as individual bundles of reduced rays through the optical path difference creating member with small-sized block portions.

[0024]

In an invention according to Claim 4, surfaces of cylindrical lenses of a first array lens on which laser light is incident have a positive convex curve, which effectively reduces reflection on side faces of the cylindrical lenses of the first array lens and provides more uniform laser light.

[0025]

In an invention according to Claim 5, a first array lens and an illumination target surface are in a conjugation relation between an object and an image. This means that shapes that beams have immediately after split by the first array lens are overlapped on

the illumination target surface, thereby reducing the influence of the source of the laser light and making it possible to illuminate the illumination target surface more uniformly. In addition, since rays conjugate between the first array lens and the illumination target surface turn into parallel rays between a second array lens and a condenser lens, placing here an optical path difference creating member that is composed of block portions does not change the conjugation relation and only the optical path difference between split rays is changed. The parallel rays are also capable of avoiding diffraction, which often takes place at the incident/exit ends of the block portions.

Brief Description of the Drawings

[0026]

[FIG. 1] A schematic diagram showing a side view of a crystallized film forming device according to an embodiment of the present invention.

[FIG. 2] A diagram showing a cylindrical lens of a first array lens whose incident surface has a positive convex curve according to an embodiment of the present invention.

[FIG. 3] A diagram showing a cylindrical lens of a first array lens whose incident surface is planar according to an embodiment of the present invention.

[FIG. 4] A schematic diagram showing a conventional crystallized film forming device.

[FIG. 5] A schematic diagram showing conventional light flux splitting means.

[FIG. 6] A schematic diagram showing another conventional crystallized film forming device.

Best Mode for carrying out the Invention

[0027]

An object of the present invention is to obtain a uniform laser by reducing reflection on side faces of an optical path difference creating member when laser light enters the optical path difference creating member as individual reduced split rays having an optical path difference.

Embodiment

[0028]

A description is given below with reference to the drawings on a preferred embodiment of a method and device for forming a crystallized film according to the present invention.

FIGS. 1 and 2 show an embodiment of a crystallized film forming device according to the present invention. In FIG. 1, a symbol A denotes a laser light source. A first array lens 2, a second array lens 3, an optical path difference creating member 7, which creates an optical path difference, a condenser lens 5, and an illumination target surface 6 are sequentially arranged along an optical axis x in a side view with respect to the laser light source A. Here, an array lens is defined as the lenticular lens or the fly's eye

lens in the prior art examples.

[0029]

The laser light source A has a light source and a positive lens (not shown). Coherent light emitted from the laser light source A is laser light 1, which is theoretically a bundle of parallel rays but actually has an inevitable divergence angle θ (< 1 mrad) due to being emitted from the laser light source A.

[0030]

The first and second array lenses 2 and 3 are built by coupling plural (five in the drawing) adjoining cylindrical lenses 2a and 3a, respectively, and constitute a homogenizer together with the condenser lens 5. The cylindrical lenses 2a of the first array lens 2 each have a focal length f_1 . The cylindrical lenses 3a of the second array lens 3 each have a focal length f_2 . The distance between the first and second array lenses 2 and 3 which are placed to extend in the same direction is set to f_2 . The laser light 1 emitted from the laser light source A is incident on the first array lens 2 to be converged and split by the cylindrical lenses 2a, and thus turned into split rays 9. The distances are set such that $f_2 > f_1$ and $f_1 > f_2/2$ are satisfied.

[0031]

The split rays 9 form, in front of the second array lens 3, as many light source images 4 as the number of the cylindrical lenses 2a of the first array lens 2. The light 9 from the light source

images 4 are separately incident on the cylindrical lenses 3a of the second array lens 3 to be turned into reduced split rays 10, which are substantially parallel to one another. The cylindrical lenses 2a of the first array lens 2 and the cylindrical lenses 3a of the second array lens 3 constitute reducing/splitting means for obtaining the reduced split rays 10 by splitting and reducing the laser light 1 and then turning the split rays 9 into individual bundles of rays substantially parallel to one another. The cylindrical lenses 2a of the first array lens 2 splits the laser light 1 into the split rays 9 while reducing the laser light 1 in a Y direction (the vertical direction in the side view of FIG. 1), which is orthogonal to the optical axis x (X direction). The cylindrical lenses 3a of the second array lens 3 turns the split rays 9 into the reduced split rays 10, which are bundles of parallel rays, while reducing the split rays 9 in the Y direction orthogonal to the optical axis x.

[0032]

When the reduced split rays 10 have a width smaller than a width d of the cylindrical lenses 2a of the first array lens 2, the reduced split rays 10 can be transmitted separately through the optical path difference creating member 7 without causing reflection on side faces at both ends in the Y direction of each of block portions 7a of the optical path difference creating member 7. The reduced split rays 10 therefore do not always need to be

bundles of strictly parallel rays. In other words, the reduced split rays 10 need only to be separately transmitted through the corresponding block portions 7a of the optical path difference creating member 7 while reducing reflection on the splitting surface side of the cylindrical lenses 2a.

[0033]

A curvature surface 11 of the cylindrical lenses 2a of the first lens array 2 on which the laser light 1 is incident to be turned into converged light is set to have a positive convex curve as shown in FIG. 2. This keeps side faces 13, which are at both ends in the Y direction of each of the cylindrical lenses 2a of the first array lens 2, from reflecting the laser light 1 having a divergence angle θ much.

[0034]

The condenser lens 5 is constructed from one large cylindrical lens that has a focal point f_c . The condenser lens 5 converges all the reduced split rays 10 which have been separately transmitted through the block portions 7a of the optical path difference creating member 7 at the same portion of the illumination target surface 6 to overlap and shape the rays. An arbitrary point P on the illumination target surface 6 is thus illuminated with light from all the light source images 4. The distance between the illumination target surface 6 and the condenser lens 5 is set to the focal length f_c of the condenser lens 5.

[0035]

The illumination target surface 6 is a surface on which a semiconductor (thin film material) to form a crystallized film is placed. This arrangement, which sets the distance between the first and second array lenses 2 and 3 to the focal length f_2 of the second array lens 3 and sets the distance between the illumination target surface 6 and the condenser lens 5 to the focal length f_c of the condenser lens 5, puts the first array lens 2 and the illumination target 6 into a conjugation relation.

[0036]

Thus, the laser light 1 emitted from the laser light source A is transmitted through the first and second array lenses 2 and 3 and the condenser lens 5, which together constitute a homogenizer, and illuminates the illumination target surface 6, thereby forming a crystallized film in a thin film material that is placed on the illumination target surface 6.

[0037]

With the first array lens 2 and the illumination target surface 6 put in a conjugation relation, beam shapes of the split rays 9 immediately after being split by the first array lens 2 are overlapped on the illumination target surface 6, and therefore the illumination target surface 6 can be illuminated uniformly.

[0038]

In addition, since rays 8 (shown in FIG. 1) conjugate between

the first array lens 2 and the illumination target surface 6 turn into parallel rays between the second array lens 3 and the condenser lens 5, placing here the optical path difference creating member 7 does not change the conjugation relation and only the optical path difference between split rays is changed. By setting f_1 and f_2 such that $f_1 > f_2/2$ is satisfied, the reduced split rays 10 are reduced before transmitted through the optical path difference creating member 7 to a width smaller than a width a of the block portions 7a constituting the optical path difference creating member 3. This suppresses reflection within the block portions 7a and turns the reduced split rays 10 into parallel rays, thereby preventing diffraction which could otherwise occur at the incident/exit ends of the block portions 7a.

[0039]

A description is given on the optical path difference creating member 7, which, in this crystallized film forming device having the laser light source A, the first array lens 2, the second array lens 3, the condenser lens 5, and the illumination target surface 6, is placed between the second array lens 3 and the condenser lens 5.

[0040]

The optical path difference creating member 7 has a function of creating an optical path difference between the reduced split rays 10 at the arbitrary point P on the illumination target surface

6 in a manner that adjusts the coherence of the laser light 1 emitted from the laser light source A, so that interference and accordingly Moire fringes are reduced or controlled. The optical path difference creating member 7 is constructed by placing N (N is larger than 1, 5 in the drawing) optical path difference creating block portions 7a in parallel. The number of the block portions 7a is determined in accordance with the number of the reduced split rays 10. In general, an optical path difference created by the optical path difference creating member 7 is set larger than the coherent length of the laser light 1 to prevent Moire fringes.

[0041]

The block portions 7a have a given refraction index larger than that of air, and have the same width a in the Y direction and different lengths L in the direction of the optical axis x. The width a of each of the block portions 7a is equal to or smaller than the width d of the cylindrical lenses 2a of the first array lens 2. The varying lengths L of the block portions 7a are set such that Moire fringes are reduced or controlled. In general, the dimensions of the block portions 7a are set to create an optical path difference larger than the coherent length between every two rays out of all the reduced split rays 10 that exit the second array lens 3.

[0042]

To be specific, the block portions 7a of the optical path

difference creating member 7 are each composed of quartz glass shaped into a quadratic prism that measures a in width and $L_1 + (N - 1) \cdot \Delta L$ in length, where L_1 represents the length of the smallest one of the block portions 7a and N represents an integer corresponding to the number of the block portions 7a. When the smallest one of the five block portions 7a made of quartz glass has a length L_1 and the difference in length between the block portions 7a is ΔL , the block portions 7a are arranged such that the one having a length $L_1 + 4 \cdot \Delta L$ is placed in the middle, the one having a length $L_1 + 3 \cdot \Delta L$ and the one having a length $L_1 + 2 \cdot \Delta L$ are placed sandwiching the middle one, and next placed is the one having a length $L_1 + 1 \cdot \Delta L$ The length difference ΔL between the block portions 7a is in general a length that creates in the laser light 1 an optical path difference larger than the coherent length.

[0043]

Thus, the reduced split rays 10 traveled from the light source images 4 and turned into substantially parallel rays by being separately incident on the cylindrical lenses 3a of the second array lens 3 are separately transmitted through the block portions 7a at their centers, and are given optical path lengths different from one optical path to another.

[0044]

The operation is described next.

The laser light 1, which is emitted from the laser light source A as a bundle of parallel rays having a divergence angle θ (< 1 mrad), is converged as the split rays 9 by the cylindrical lenses 2a of the first array lens 2 to form as many light source images 4 as the number of the cylindrical lenses 2a on the same plane in front of the second array lens 3. The split rays 9 from the light source images 4 are separately incident on the cylindrical lenses 3a of the second array lens 3 to be turned into substantially parallel rays.

[0045]

The laser light 1 emitted from the coherent light source A and given a divergence angle θ is transmitted through the first array lens 2, which has a focal length f_1 and which is composed of N cylindrical lenses 2a each having a lens width d , and then through the second array lens 3, which has a focal length f_2 and N cylindrical lenses 3a each having the width d . Split and reduced by the splitting/reducing means (2 and 3), the laser light 1 is turned into the split rays 9, which are then turned into the split reduced rays 10 composed of individual bundles of parallel rays.

[0046]

When $f_1 < f_2$ is satisfied, the light source images 4 are formed between the first array lens 2 and the second array lens 3. When $f_1 > f_2/2$ is satisfied, the split rays 9 can be transmitted through the centers of the cylindrical lenses 3a of the second array lens

3 whose width d is equal to or smaller than the width d of the cylindrical lenses 2a of the first array lens 2. Transmitting the split rays 9 through the cylindrical lenses 3a at their centers reduces reflection on side faces of the second array lens 3.

[0047]

Reflection on side faces of the first array lens 2 is also reduced since the curvature surface 11 of the cylindrical lenses 2a of the first lens array 2 on which the laser light 1 is incident is set to have a positive convex curve as shown in FIG. 2.

[0048]

The laser light 1 emitted from the laser light source A as a bundle of parallel rays has a slight divergence angle θ (< 1 mrad) and, therefore, if reflected a lot inside the cylindrical lenses 2a after being incident on the lenses 2a, the influence of the reflected light is manifested as non-uniform light on the illumination target surface 6 that cannot be ignored.

[0049]

The reflected light can be eliminated completely, or reduced to a degree that does not affect the uniformity of the illumination light, by setting the radius of the curvature surface 11 of the cylindrical lenses 2a of the first array lens 2 on which the laser light 1 is incident to have a convex curve as shown in FIG. 2, so that the laser light 1 is turned into converged light immediately after being incident and thus avoiding reflection on the inner side

faces 13 at both ends in the Y direction of each of the cylindrical lenses 2a as much as possible. With a cylindrical lens 2a' having a planar (or concave) incident surface 11' as shown in FIG. 3, the laser light 1 having a divergence angle θ is refracted and then totally reflected at side faces 13' in the Y direction of an array lens 2', thus producing a lot of reflected light. The reflected light is incident not only on the corresponding one of the cylindrical lenses 3a of the second array lens 3 but also on the adjacent cylindrical lenses 3a that are not intended to receive light from this particular cylindrical lens 2a'. The cylindrical lenses 2a of the first array lens 2 can have planar surfaces for their exit surfaces 12.

[0050]

The reduced split rays 10 transmitted through the second array lens 3 in this manner are now transmitted, as bundles of substantially parallel rays narrower than the width d, through the block portions 7a of the optical path difference creating member 7. At this point, reflection and diffraction are not observed in the optical path difference creating member 7, particularly on side faces at both ends in the Y direction. The width a in the Y direction of the block portions 7a of the optical path difference creating member 7 is equal to or smaller than the width d in the Y direction of the lenses 2a of the first array lens 2.

[0051]

After exiting the corresponding block portions 7a of the optical path difference creating member 7, the reduced split rays 10 are transmitted through the condenser lens 5, which has a focal length f_c , and turned into overlapped and shaped laser light to illuminate the illumination target surface 6. With the condenser lens 5 distanced from the illumination target surface 6 by the focal length f_c , the reduced split rays 10 transmitted through the condenser lens 5 as bundles of parallel rays are collected on the illumination target surface 6. The collected light illuminates the illumination target surface 6 and forms a crystallized film on a semiconductor surface that is placed on the illumination target surface 6.

[0052]

In general, the reduced split rays 10 exiting the block portions 7a of the optical path difference creating member 7 are substantially incoherent and can therefore prevent Moire fringes on the illumination target surface 6, with the result that a thin film-like material is irradiated with shaped and highly uniform laser light 1. This makes it possible to obtain a crystallized film that is excellent in uniformity throughout the plane in terms of, for example, having uniform crystal grain size.

[0053]

Since the first array lens 2 and the illumination target surface 6 are conjugate with each other, an arbitrary point in the

first array lens 2 is collected to the arbitrary point P on the illumination target surface 6 irrespective of the length L of the optical path difference creating member 7. It also prevents diffraction that is otherwise often occurs at the incident/exit ends of the block portions 7a.

[0054]

When a laser beam shaped by this optical system is used to crystallize an a-Si film, for example, a solid-state laser can be employed for a laser annealing device, which has conventionally been composed of a low-coherent excimer laser.

[0055]

The laser light source A that emits excimer laser light uses active gas, and therefore requires such maintenance as gas exchange every few days. With a solid-state laser, an apparatus that does not need this kind of maintenance can be constituted. A solid-state laser are superior also in terms of having excellent pulse energy fluctuation ratio (it is said that a solid-state laser has a fluctuation ratio of 1 ~ 2% whereas an excimer laser has a fluctuation ratio of 4 ~ 6%), having high repetition frequency (a solid-state laser has a repetition frequency of 10 ~ 20 kHz while an excimer laser has a repetition frequency of 300 ~ 400 kHz), and having linear polarization (the polarization of an excimer laser is random polarization). Crystallizing a thin film-like material by making use of the characteristics of a solid-state laser is

expected to be effective in improving the uniformity of crystal grains of the film, increasing the crystal grain size, and the like.

[0056]

An actually measured optical path difference ΔL_a that does not cause interference is 3 mm when a laser light source employed as the coherent laser light source A in the above crystallized film forming device emits the laser light 1 of $\lambda = 532$ nm, which is twice the harmonic wave of a YAG laser. The difference ΔL in length between the block portions 7a is accordingly set to 5 mm to be longer than (the refractive index of quartz - the refractive index of air) $\cdot 3$ mm = 4.5 mm. Five (N) quadratic prisms are employed as the block portions 7a constituting the optical path difference creating member 7, and uniformized laser beams (reduced split rays 10) are overlapped to illuminate a thin a-Si film that is formed on a glass having a thickness of 50 nm and placed on the illumination target surface 6. As a result, a crystallized Si film of excellent uniformity is obtained.

[0057]

It is also possible to control the shape of crystals by generating light flux interference as the one described in JP 10-256152 A and controlling the cycle of the heat density distribution when an optical path difference created between the block portions 7a constituting the optical path difference creating member 7 is equal to or slightly shorter than the coherent length

of the laser light 1. That is, in order to grow large crystal grains, it is important to adjust the intensity of laser light and control the density of remaining nuclei as well as the position where nuclei are generated. An effective way is to give laser light a cyclic intensity distribution of a few μm and form remaining nuclei in low-intensity portions. This cyclic intensity distribution of the laser light can be obtained by creating an optical path difference equal to or slightly shorter than the coherent length between the reduced split rays 10 and generating laser light interference through adjustment of the coherence.

[0058]

As described above, the reduced split rays 10 are separately transmitted through the corresponding block portions 7a of the optical path difference creating member 7 while reducing reflection on the splitting surface side, an optical path difference is created between the reduced split rays 10 so that the coherence is adjusted, and then the reduced split rays 10 are overlapped by the condenser lens 5 to illuminate the illumination target surface 6 and form a crystallized film on the illumination target surface 6. Thus, uniform laser light is obtained from the laser light 1 as a bundle of parallel rays having a divergence angle θ by reducing reflection on side faces of the optical path difference creating member 7 when the laser light 1 is turned into individual bundles of reduced rays and then turned into the reduced split rays 10. Only the reduced

split rays 10 are transmitted through the block portions 7a of the optical path difference creating member 7 on a one-on-one basis, so that the obtained laser light 1 is uniform. In this way, interference among laser beams is effectively controlled and crystal grains of uniform size can be obtained through crystallization of a thin film-like material with uniform laser light.

[0059]

The plural block portions 7a of the optical path difference creating member 7, which, in Embodiment 1 described above, are a group of individual block portions 7a, may be formed in a single optical path difference creating member 7 that is shaped like a staircase.

Industrial Applicability

[0060]

The present invention is not limited to a semiconductor exposure apparatus but is also applicable to the field of image forming such as printers.

Claims

[1] A method of forming a crystallized film, characterized by comprising:

sequentially arranging a first array lens (2), a second array lens (3), an optical path difference creating member (7), a condenser lens (5), and an illumination target surface (6) in a side view with respect to a laser light source (A) which emits laser light (1) as a bundle of rays having a divergence angle (θ), the first array lens (2) being composed of plural cylindrical lenses (2a), the second array lens (3) being composed of plural cylindrical lenses (3a), the optical path difference creating member (7) having plural block portions (7a) that create an optical path difference;

transmitting the laser light (1) emitting from the laser light source (A) through the first array lens (2) to obtain as many split rays (9) that have been reduced as the number of the adjoining cylindrical lenses (2a) of the first array lens (2), the cylindrical lenses (2a) each having a width (d);

transmitting the split rays (9) separately through the corresponding cylindrical lenses (3a) of the second array lens (3) to obtain reduced split rays (10) which are each narrower than the width (d) of the cylindrical lenses (2a) of the first array lens (2);

transmitting the reduced split rays (10) separately through the corresponding block portions (7a) of the optical path difference

creating member (7) while reducing reflection on the side of splitting surfaces, to create an optical path difference between the reduced split rays (10) in a manner in which the coherence is adjusted; and

overlapping the reduced split rays (10) through the condenser lens (5) to illuminate the illumination target surface (6).

[2] The method of forming a crystallized film according to Claim 1, characterized in that a difference (ΔL) in length between the block portions (7a) of the optical path difference creating member (7) is set such that an optical path difference larger than a coherent length is created between the reduced split rays (10).

[3] The method of forming a crystallized film according to Claim 1 or 2, characterized in that a width (d) of each of the block portions (7a) of the optical path difference creating member (7) is equal to or smaller than the width (d) of each of the cylindrical lenses (2a) of the first array lens (2).

[4] A method of forming a crystallized film according to Claim 1, 2, or 3, characterized in that an incident surface (11) of the cylindrical lenses (2a) of the first array lens (2) on which the laser light (1) is incident has a positive convex curve.

[5] The method of forming a crystallized film according to Claim 1, 2, 3, or 4, characterized in that the first array lens (2) and the illumination target surface (6) are in a conjugation relation.

[6] A crystallized film forming device for illuminating an illumination target surface (6) with shaped laser light (1) emitted from a laser light source (A) as a bundle of rays that have a divergence angle (θ), characterized by comprising:

splitting/reducing means (2, 3) for splitting and reducing the laser light (1) into plural split rays (9) in one side view of the laser light source (A), and then turning the split rays (9) into individual bundles of reduced rays to obtain reduced split rays (10);

an optical path difference creating member (7) having block portions (7a), through which the reduced split rays (10) are individually transmitted while reducing reflection on the side of splitting surfaces, to thereby create an optical path difference between the reduced split rays (10) in a manner in which the coherence is adjusted; and

a condenser lens (5) for collecting the reduced split rays (10) that have been transmitted through the optical path difference creating member (7), and characterized in that

the illumination target surface (6) is illuminated with laser

light overlapped through the condenser lens (5).