Description

Title of Invention: LASER LINE BEAM IMPROVEMENT APPARATUS AND LASER PROCESSING APPARATUS

Technical Field

[0001]

This invention relates to a laser line beam improvement apparatus that improves an intensity distribution of a line beam and to a laser processing apparatus including the laser line beam improvement apparatus.

Background Art

[0002]

A method of irradiating an object to be processed with a laser to anneal the object is implemented for crystallization of an amorphous semiconductor, activation of semiconductor impurities, and the like. In this laser annealing process, the beam profile of the laser is formed into a predetermined profile through an optical system, and the beam intensity is uniform (top flat: flat section) in beam cross section. The beam is condensed as necessary to irradiate the object to be processed.

[0003]

A line beam profile with a minor axis width and a major axis width in beam cross-sectional view is known as

a type of beam profile, and the object to be processed can be irradiated while scanning the line beam profile to collectively and efficiently process a wide area of the object to be processed. However, after going through various optical members and the like, even the top-flat line beam profile includes parts (also called steepness sections) where the energy intensity decreases toward the outside, at edges in the minor axis direction and the major axis direction. On the minor axis side, the width of the steepness sections is small due to a reduction in the beam width after condensing or the like, and scanning is performed by overlap irradiation in the minor axis direction. Therefore, the effect of steepness section irradiation is reduced. On the other hand, irradiation is performed with the steepness sections having a large width on the major axis side, and the width is usually about 250 times that of the minor axis direction. A part of the object to be processed irradiated with the steepness sections on the major axis side is irradiated with a laser at an energy intensity different from that of the part irradiated with a flat section, resulting in a different processing state. Therefore, the part of the object to be processed irradiated with the steepness sections on the major axis side is usually not used as a product.

[0004]

A technique of arranging slits for removing or reducing attenuation sections equivalent to the steepness sections is proposed (for example, see Patent Literature 1).

The steepness sections are removed or reduced in the line beam transmitted through the slits, and the irradiation area of steepness can be reduced in the object to be processed irradiated with the line beam. If permitted in terms of quality, the irradiation area of the steepness sections can be included in the product.

Citation List

Patent Literature

[0005]

Patent Literature 1: Japanese Patent Laid-Open No. 2002-252455

Summary of Invention

Technical Problem

[0006]

The steepness sections are further generated in the line beam transmitted through the slits due to diffraction and the like after the transmission. With an increase in the distance after the transmission, the steepness sections are extended, and the width increases. Therefore, the smaller the distance from the slits to the

object to be processed, the smaller the width of the steepness sections.

However, the minor axis side of the line beam is usually condensed to irradiate the object to be processed, and the energy density increases with a decrease in the distance to the object to be processed. The slits are easily damaged if the slits are arranged at positions near the object to be processed, and the durability is significantly reduced. Fine fragments are further generated from the damaged slits, and may be mixed into the object to be processed as contaminations. Particularly, the energy density per unit time of a pulsed laser is higher than that of a continuous wave laser, and the problem becomes prominent. On the other hand, if the slits are arranged at positions far from the object to be processed, the degree of condensing is small, and the minor axis width is relatively large. Therefore, the energy density is relatively small, and the damage to the slits can be reduced. However, if the slits are at positions far from the object to be processed, the steepness sections generated in the line beam transmitted through the slits are significantly extended subsequently. The width of the steep sections increases, and the effect of shielding the steepness sections is reduced.

[0007]

When laser processing is executed to reserve a plurality of panel areas on a semiconductor substrate,

the irradiation is performed so that the steepness sections are positioned at gaps between the panels. The smaller the gaps between the panels, the more the number of panels that can be cut out from one semiconductor substrate. Therefore, there is a demand for reducing the width of the steepness sections to reduce the gaps between the panels. Recently, there is an increasing demand for line beam irradiation of a semiconductor with reduced intervals of transistor areas (including expected areas) in order to efficiently form transistors. In the line beam irradiation, the irradiation areas of the steepness sections need to be within the intervals of the transistor areas. In this case, there is also a demand for reducing the width of the steepness sections.

However, it is difficult to meet the demands in the conventional slits while suppressing the damage of the slits.

[0008]

The present invention has been made in view of the circumstances, and an object of the present invention is to provide a laser line beam improvement apparatus and a laser processing apparatus that can reduce damage of shielding portions and that can effectively reduce steepness sections generated in a line beam.

Solution to Problem

[0009]

More specifically, a first invention of a laser line beam improvement apparatus of the present invention includes: a first shielding portion that is arranged at a position relatively far from an object to be processed on an optical path of a line beam emitted to the object to be processed and that shields transmission of major axis end sections of the line beam; and a second shielding portion that is arranged at a position relatively near the object to be processed and that further shields the transmission of the major axis end sections of the line beam after the shielding of the transmission of the major axis end sections by the first shielding portion.

[0010]

A second invention provides the laser line beam improvement apparatus according to the first invention, wherein the line beam includes a flat section and steepness sections positioned at minor axis end sections and the major axis end sections in a beam intensity profile.

[0011]

A third invention provides the laser line beam improvement apparatus according to the second invention, wherein the flat section is an area with an intensity that is 97% or more of a maximum intensity in the beam intensity profile.

[0012]

A fourth invention provides the laser line beam improvement apparatus according to the second invention, wherein the first shielding portion shields the transmission of the steepness sections of the major axis end sections of the line beam and the transmission of major axis side end sections of the flat section of the line beam.

[0013]

A fifth invention provides the laser line beam improvement apparatus according to any of the first to fourth inventions, wherein the second shielding portion performs the shielding at the same position or outside of the first shielding portion in a major axis direction of the line beam.

[0014]

A sixth invention provides the laser line beam improvement apparatus according to any of the first to fifth inventions, wherein the second shielding portions include a plurality of shielding portions at different far-and-near positions relative to the object to be processed, the plurality of shielding portions further shielding the transmission of the major axis end sections of the line beam after the shielding of the transmission of the major axis end sections of the line beam by the shielding portion of a former stage.

[0015]

A seventh invention provides the laser line beam improvement apparatus according to the sixth invention, wherein in the plurality of shielding portions, the shielding portion of a later stage performs the shielding at the same position or outside of the shielding portion of the former stage.

[0016]

An eighth invention provides a laser processing apparatus including: a laser light source that outputs a laser; an optical system that forms a beam profile of the laser into a line beam and guides the laser; a processing chamber that is provided with an object to be processed and that introduces the laser guided by the optical system through an introduction window to emit the laser to the object to be processed; and the laser line beam improvement apparatus according to any of the first to seventh inventions, wherein the first shielding portion of the line beam improvement apparatus is arranged outside of the processing chamber, between a condensing lens at a final stage of the optical system and the introduction window, and the second shielding portion of the line beam improvement apparatus is arranged in the processing chamber inside of the introduction window.

[0017]

A ninth invention provides the laser processing apparatus according to the eighth invention that emits the laser to the object to be processed and that is used

in a crystallization or activation process of the object to be processed.

[0018]

According to the present invention, the first shielding portion shields the transmission of the major axis end sections of the line beam at a stage in which the degree of condensing on the minor axis side is small, and the energy density is not high. The second shielding portion further shields the transmission of the major axis end sections of the line beam with reduced steepness sections, and the steepness sections are effectively reduced.

The first shielding portion is in a stage in which condensing on the minor axis side is gentle, and the damage to the first shielding portion can be reduced with the steepness sections reduced. The extension of the steepness sections extended after the transmission through the first shielding portion is smaller than that of the steepness sections reaching the first shielding portion. The second shielding portion can shield the transmission of the major axis side end sections of the line beam, and the extension of the steepness sections can be smaller.

The cross-sectional area of the steepness sections, which are shielded by the second shielding portion, emitted to the second shielding portion is smaller than when the steepness sections are emitted to the second

shielding portion without the shielding, and the damage to the second shielding portion can be reduced. All or only part of the steepness sections can be shielded by the second shielding portions, and the irradiation cross-sectional area emitted to the second shielding portion can be minimized. Since the line beam transmitted through the second shielding portion transmits through the second shielding portion at a position near the object to be processed, the extension of the steepness sections caused by diffraction or the like after the transmission through the second shielding portion is small, and the line beam is applied to the object to be processed while the width of the steepness sections remains small. If only part of the outer part of the steepness sections in the major axis direction is shielded by the second shielding portion, the irradiation energy of the steepness sections applied to the second shielding portion is further reduced, and the damage to the second shielding portion is further reduced.

[0019]

The line beam includes: a flat section; and steepness sections at least on the major axis side. The flat section can be an area with an energy intensity that is 97% or more of the maximum energy intensity of the beam cross section. However, the present invention is not limited to this. At both end sections of the flat section, the line beam includes the steepness sections in

which the energy intensity is lower than that of the flat section, and the intensity gradually decreases toward the outside.

The line beam profile denotes a profile in which the ratio of the major axis to the minor axis is large, and for example, the ratio can be 10 or more. Although the length of the major axis side and the length of the minor axis side are not particularly limited in the present invention, an example of the length of the major axis side is 370 to 1300 mm, and an example of the length of the minor axis side is 100 μm to 500 μm.

[0020]

Although the first shielding portion and the second shielding portion prevent the transmission of the major axis side end sections of the line beam, the shielding portion can completely block the transmission, or the shielding portion can reduce the transmittance to reduce the transmission. In this case, it is desirable that the transmittance is 50% or less. The method and the extent of shielding can vary between the first shielding portion and the second shielding portion. For example, one of the shielding portions (for example, first shielding portion) can block the line beam, and the other shielding portion (for example, second shielding portion) can suppress the transmission.

[0021]

The first shielding potion can be arranged to shield at least the steepness sections at both end sections on the major axis side of the line beam, and the first shielding portion can be arranged to shield part of the outer part of the steepness sections. All of the steepness sections and part of the flat section can be shielded to surely reduce the steepness sections. The degree of condensing on the minor axis side is low in the first shielding portion, and thus the damage to the shielding portion is relatively small even if the flat section side is shielded.

The second shielding portion can be arranged to shield at least the steepness sections of the line beam transmitted through the first shielding portion. In this case, the second shielding portion can shield part of the outer part of the steepness sections. Preferably, the steepness sections formed after the transmission through the first shielding portion can be shielded. The shielding position of the first shielding portion and the shielding position of the second shielding portion can be the same position in the major axis direction of the line beam (for example, based on the center in the major axis direction), or the shielding position of the second shielding portion can be outside of the shielding position of the first shielding portion.

[0022]

As for the arrangement positions of the first shielding portion and the second shielding portion in the far-and-near direction on the optical path, the first shielding potion can be relatively far from the object to be processed, and the second shielding portion can be relatively near the object to be processed. The relative far-and-near relationship is a relationship between the first shielding portion and the second shielding portion based on the object to be processed. Although the arrangement positions of the shielding portions are not particularly limited in the present invention as long as the positions have this relative relationship, based on the laser light introduction window of the processing chamber, the present invention illustrates the first shielding portion placed outside of the introduction window and illustrates the second shielding portion placed inside of the introduction window. If the first shielding portion is placed outside of the introduction window, the first shielding portion can be arranged at an appropriate position in this area. If the second shielding portion is placed inside of the introduction window, the second shielding portion can be arranged at an appropriate position in this area according to the object to be processed, for example.

The second shielding portion can include a plurality of shielding portions at different relative far-and-near positions. In this case, the shielding portion of the

former stage can shield the steepness sections of the line beam, and the shielding portion of the later stage can block the steepness sections generated by the transmitted line beam.

In this case, the shielding portion of the later stage can performs the shielding at the same positions or outside of the shielding portions of the former stage.

Advantageous Effects of Invention

[0023]

As described, according to the present invention, the steepness sections generated in the line beam can be effectively reduced, and the process using this can be favorably executed. Furthermore, the damage of the shielding portions can be reduced when the minor axis direction of the line beam is condensed.

Brief Description of Drawings

[0024]

[Figure 1] Figure 1 is a schematic diagram showing a laser line beam improvement apparatus and a laser processing apparatus according to an embodiment of the present invention.

[Figure 2] Figure 2 is a plan view showing shielding portions and a line beam transmitting through the shielding portions according to the embodiment of the present invention.

[Figure 3] Figure 3 is a diagram viewed from the front side of the line beam transmitting through the shielding portions according to the embodiment of the present invention.

[Figure 4] Figure 4 is a diagram viewed from the front side of the line beam transmitting through the shielding portions according to another embodiment of the present invention.

[Figure 5] Figure 5 is a diagram viewed from the front side of the line beam transmitting through conventional slits.

[Figure 6] Figure 6 is a diagram showing a major axis beam profile of the line beam.

Description of Embodiments

[0025]

Hereinafter, a laser line beam improvement apparatus and a laser processing apparatus including the laser line beam improvement apparatus according to an embodiment of the present invention will be described with reference to the attached drawings.

Figure 1 shows a laser annealing apparatus 1 equivalent to the laser processing apparatus. The laser annealing apparatus 1 includes a processing chamber 2, includes a scanning apparatus 3 that can move in an X-Y direction in the processing chamber 2, and includes a base 4 above the scanning apparatus 3. A substrate

arrangement board 5 as a stage is provided on the base 4. A motor not shown or the like drives the scanning apparatus 3.

An introduction window 6 for introducing a pulsed laser from the outside is provided on the processing chamber 2.

[0026]

During an annealing process, an amorphous silicon film 100 or the like as a semiconductor film is installed on the substrate arrangement board 5. The silicon film 100 is formed with a thickness of, for example, 40 to 100 nm (specifically, thickness of 50 nm for example) on a substrate not shown. The formation can be performed by an ordinary method, and the formation method of the semiconductor film is not particularly limited in the present invention.

Although laser processing of crystallizing the amorphous film by laser processing is described in the present embodiment, the details of the laser processing are not limited to this in the present invention. For example, single crystallization of a non-single crystal semiconductor film can be performed, or a crystal semiconductor film can be modified. The present invention can be related to other processes, and the object to be processed is not limited to a specific object.

[0027]

A pulsed laser light source 10 is installed outside of the processing chamber 2. The pulsed laser light source 10 includes an excimer laser oscillator (trade name: LSX315C), and a pulsed laser with a wavelength of 308 nm and a repeated oscillation frequency of 300 Hz can be output. In the pulsed laser light source 10, feedback control can control and maintain the output of the pulsed laser within a predetermined range. The type of the pulsed laser light source is not limited to the one described above.

[0028]

An attenuator 11 adjusts, as necessary, the energy density of a pulsed laser 15 oscillated and output by the pulsed laser light source 10. An optical system 12 including optical members, such as a homogenizer 12a, a reflection mirror 12b, and a condensing lens 12c, forms the pulsed laser 15 into a line beam profile or deflects the pulsed laser 15. The pulsed laser 15 is emitted to the amorphous silicon film 100 in the processing chamber 2 through the introduction window 6 provided on the processing chamber 2. The optical members included in the optical system 12 are not limited to the ones described above, and various lenses, mirrors, waveguide portions, and the like can be included.

[0029]

First shielding plates 20 equivalent to a first shielding portion are arranged between the condensing

lens 12c and the introduction window 6, and second shielding plates 21 equivalent to second shielding portions are arranged in the processing chamber 2. As shown in Figure 2, the first shielding plates 20 are arranged so that the tips of a pair of shielding plates face each other, and a first transmission gap 20a is reserved between the shielding plates. The first transmission gap 20a has a gap with a length that allows shielding end sections in the major axis direction of a pulsed laser 150. Similarly, the second shielding plates 21 are arranged so that the tips of a pair of shielding plates face each other, and a second transmission gap 21a is reserved between the shielding plates. The second transmission gap 21a has a gap with a length that allows shielding end sections in the major axis direction of the pulsed laser 150 transmitted through the second shielding plates 21. The first shielding plates 20 and the second shielding plates 21 constitute the laser line beam improvement apparatus of the present invention.

The pairs of shielding plates of the first shielding plates 20 and the second shielding plates 21 can be automatically or manually moved to adjust the gaps between the shielding plates.

[0030]

Next, operation of the laser annealing apparatus 1 will be described.

The pulse full width at half maximum of the pulsed laser 15 oscillated and output by the pulsed laser light source 10 is, for example, 200 ns or less. However, the present invention is not limited to these.

The attenuator 11 adjusts the pulse energy density of the pulsed laser 15. The attenuator 11 is set to a predetermined attenuation factor, and the attenuation factor is adjusted to obtain a predetermined irradiation pulse energy density on the irradiation surface of the semiconductor film. For example, in the crystallization of the amorphous silicon film 100, the attenuation factor can be adjusted so that the energy density is 100 to 500 mJ/cm^2 on the irradiation surface.

[0031]

The optical system 12 forms the pulsed laser 15 transmitted through the attenuator 11 into a line beam profile. The minor axis width of the pulsed laser 15 is condensed through the condensing lens 12c, such as a cylindrical lens, of the optical system 12, and the pulsed laser 15 is introduced into the introduction window 6 provided on the processing chamber 2. Figure 6 shows a beam intensity profile in the major axis direction of the line beam 150 emitted from the optical system 12. The profile illustrated in Figure 6 is simplified.

The line beam 150 includes: a flat section 151 with an energy intensity that is 97% or more of the maximum

energy intensity; and steepness sections 152 that are positioned at both end sections in the major axis direction and that have an energy intensity smaller than that of the flat section 151, wherein the energy intensity gradually decreases toward the outside. Although a major axis direction width 152a of the steepness sections is not particularly limited, the width is usually about 1 mm to 25 mm, in which the energy intensity decreases to 10% of the maximum intensity. The percentage of the flat section relative to the maximum energy intensity can be appropriately determined.

[0032]

The first transmission gap 20a of the first shielding plates 20 is arranged to shield the line beam 150 up to positions partially extended into the steepness sections 152 at both ends and the flat section 151 as shown in Figure 2 and Figure 3.

The line beam 150 with the reduced steepness sections 152 passes through the first transmission gap 20a of the first shielding plates 20 as shown in Figure 2, and steepness sections 153 are formed at both end sections in the major axis direction due to diffraction and the like. However, the steepness sections 153 are formed by shielding the steepness sections 152, and thus the extension width is significantly smaller than that of the steepness sections 152.

[0033]

The line beam 150 including the steepness sections 153 transmits through the introduction window 6 and is introduced into the processing chamber 2.

The line beam 150 further advances and reaches the second shielding plates 21 as shown in Figure 2 and Figure 3. In the second shielding plates 21, the major axis direction width of the second transmission gap 21a is longer than the major axis direction width of the first transmission gap 20a, and the steepness sections 153 of the line beam 150 are positioned at ends in the major axis direction of the second transmission gap 21a. Therefore, in the second shielding plates 21, the remaining part of the steepness sections 153 is shielded except for part of the steepness sections 153 inside in the major axis direction. Although steepness sections 154 are formed by diffraction and the like in the line beam 150 passed through the second transmission gap 21a as shown in Figure 2(c) and Figure 3, the extension width is further reduced compared to the steepness sections 153, and the steepness sections are reduced.

How much the second shielding plates 21 shield the inside of the steepness sections 153 can be appropriately set. In this case, the amount of shielding can be set by considering the damage of the second shielding plates 21 and the extension width of the steepness sections 153 to be reduced.. In this example, the major axis direction

width of the second transmission gap 21a is set according to the width of the flat section 151.

[0034]

The second shielding plates 21 are arranged at positions relatively close to the silicon film 100, and the line beam 150 transmitted through the second shielding plates 21 is applied to the silicon film 100 without significant extension of the steepness sections 153.

In the annealing process in which the line beam 150 is emitted while the scanning apparatus 3 moves the silicon film 100 to perform relative scanning, the width of the area of the irradiation of the steepness sections 154 is relatively small, and the wasted area can be reduced. For the demand for executing the process with the arrangement intervals of the transistors reduced, the steepness sections 154 can be positioned at the intervals to favorably crystallize the areas of the transistors by the flat section 151.

The speed of the scan in the present invention is not particularly limited to a specific speed, and for example, the speed can be selected from a range of 1 to 100 mm/second.

[0035]

Although the first shielding plates 20 equivalent to the first shielding portion and the second shielding plates 21 equivalent to the second shielding portion are

included in the description of the embodiments, a plurality of shielding plates equivalent to the second shielding portion can be provided along the optical path of the line beam, and each shielding plate can shield the steepness section. Figure 4 shows an example including the second shielding plates 21 and third shielding plates 22 as the second shielding portion, and the number of the second shielding plates is not particularly limited in the present invention. As in the other shielding plates, the tips of a pair of shielding plates face each other in the third shielding plates 22. The third shielding plates 22 are arranged with a gap between the plates, and a third transmission gap 22a is reserved between the plates. The third shielding plates 22 can also be automatically or manually moved to adjust the gap between the pair of shielding plates.

The line beam 150 transmits through the third transmission gap 22a of the third shielding plates 22, and the steepness sections can be further reduced.

In the third shielding plates 22 positioned in the later stage of the second shielding plates 21, the inner ends of the shielding positions can be at the same positions or outside of the second shielding plates in the major axis direction.

[0036]

Meanwhile, Figure 5 is an example of shielding the line beam 150 by conventional slit portions 25. When the

slit portions 25 are arranged relatively far from the silicon film 100 to reduce the damage to the slit portions 25, the slit portions 25 shield the steepness sections 152, and then the steepness sections 153 formed by diffraction are gradually extended. The width of the steepness sections increases, and the shielding effect by the slit portions is reduced. Therefore, sufficient laser line beam improvement effect cannot be obtained.

[0037]

Although the shielding plates are included as the shielding portion in the description of the embodiments, the shielding portion can be a slit portion including slits.

[0038]

Although the present invention has been described based on the embodiments, the present invention is not limited to the content of the embodiments, and appropriate changes can be made without departing from the scope of the present invention.

Reference Signs List

[0039]

1 laser annealing apparatus

2 processing chamber

3 scanning apparatus

5 substrate arrangement board

6 introduction window

10 pulsed laser light source

11 attenuator

12 optical system

12c condensing lens

20 first shielding plate

20a first transmission gap

21 second shielding plate

21a second transmission gap

22 third shielding plate

22a third transmission gap

100 silicon film

Claims

[Claim 1]

A laser line beam improvement apparatus comprising:

a first shielding portion that is arranged at a position relatively far from an object to be processed on an optical path of a line beam emitted to the object to be processed and that shields transmission of major axis end sections of the line beam; and

a second shielding portion that is arranged at positions relatively near the object to be processed and that further shields the transmission of the major axis end sections of the line beam after the shielding of the transmission of the major axis end sections by the first shielding portion.

[Claim 2]

The laser line beam improvement apparatus according to claim 1, wherein

the line beam includes a flat section and steepness sections positioned at minor axis end sections and the major axis end sections in a beam intensity profile.

[Claim 3]

The laser line beam improvement apparatus according to claim 2, wherein

the flat section is an area with an intensity that is 97% or more of a maximum intensity in the beam intensity profile.

[Claim 4]

The laser line beam improvement apparatus according to claim 2, wherein

the first shielding portion shields the transmission of the steepness sections of the major axis end sections of the line beam and the transmission of major axis side end sections of the flat section of the line beam.

[Claim 5]

The laser line beam improvement apparatus according to any of claims 1 to 4, wherein

the second shielding portion performs the shielding at the same position or outside of the first shielding portion in a major axis direction of the line beam.

[Claim 6]

The laser line beam improvement apparatus according to any of claims 1 to 5, wherein

the second shielding portion includes a plurality of shielding portions at different far-and-near positions relative to the object to be processed, the plurality of shielding portions further shielding the transmission of the major axis end sections of the line beam after the shielding of the transmission of the major axis end sections of the line beam by the shielding portion of a former stage.

[Claim 7]

The laser line beam improvement apparatus according to claim 6, wherein

in the plurality of shielding portions, the shielding portion of a later stage performs the shielding at the same position or outside of the shielding portion of the former stage.

[Claim 8]

A laser processing apparatus comprising:

a laser light source that outputs a laser;

an optical system that forms a beam profile of the laser into a line beam to guide the laser;

a processing chamber that is provided with an object to be processed and that introduces the laser guided by the optical system through an introduction window to emit the laser to the object to be processed; and

the laser line beam improvement apparatus according to any of claims 1 to 7, wherein

the first shielding portion of the line beam improvement apparatus is arranged outside of the processing chamber, between a condensing lens at a final stage of the optical system and the introduction window, and

the second shielding portion of the line beam improvement apparatus is arranged in the processing chamber inside of the introduction window.

[Claim 9]

The laser processing apparatus according to claim 8 that emits the laser to the object to be processed and

that is used in a crystallization or activation process of the object to be processed.