DESCRIPTION

LASER ANNEALING APPARATUS

BACKGROUND OF THE INVENTION

Technical Field of the Invention

[0001]

The present invention relates to a laser annealing apparatus for performing an annealing treatment on a workpiece to be processed by irradiating the workpiece with laser light.

Description of the Related Art

[0002]

In recent years, a thin film transistor (TFT) in which a polysilicon film is used for a channel layer has been widely used as a switching element of a semiconductor device and a liquid crystal display. The polysilicon film used for the channel layer of the thin film transistor is generally manufactured using a process called a low-temperature polysilicon. The low-temperature polysilicon is a process of forming an amorphous silicon film on a glass substrate and irradiating the amorphous silicon film with a laser light to produce a polysilicon film.

[0003]

In such a low-temperature polysilicon, the amorphous silicon film is heated, melted, and recrystallized to produce a polysilicon film using a laser

annealing apparatus. However, the low-temperature polysilicon has a problem in that if oxygen is included in the annealing atmosphere, the silicon is oxidized during heating to have an adverse effect on the device characteristics. For this reason, an operation of preventing oxidation of silicon using an inert gas such as nitrogen is performed.

[0004]

In Patent Document 1, a stage on which a glass substrate is placed is provided in a processing chamber so as to supply nitrogen gas into the processing chamber, thus preventing oxidation of silicon during an annealing treatment.

In Patent Document 2, nitrogen is discharged from a tip end of a swing nozzle that swings up and down so as to create a nitrogen atmosphere only in the vicinity of a laser irradiation portion, thus preventing oxidation of silicon during an annealing treatment.

In Patent Document 3, in a state in which a cylindrical cell of which the top portion is sealed by glass and the bottom portion is open is disposed at a position sufficiently close to a substrate, nitrogen gas is filled into the cell, thus preventing oxidation of silicon during annealing.

[0005]

[Patent Document 1] Japanese Patent No. 3735394

[Patent Document 2] Japanese Patent No. 3091904

[Patent Document 3] Japanese Unexamined Patent Application Publication No. 2004-87962

[0006]

When the laser annealing using the supply of nitrogen as described above is performed, due to a difference in the flow rate of the nitrogen gas and variation in the ambient air temperature resulting from the change of seasons or the like, a problem that the process becomes unstable occurs, such as the occurrence of irradiation unevenness.

The present inventors have carried out intensive investigations into the cause of the occurrence of such irradiation unevenness and found that a refraction phenomenon of laser light resulting from fluctuation (variation) in the temperature of the nitrogen gas was the cause. In Japanese Unexamined Patent Application Publication No. H11-176730, it is described in regard to a laser interference length measuring machine that variation in the refractive indices of air has an influence on the precision of an optical sensor, which supports the idea of the present inventors.

SUMMARY OF THE INVENTION

[0007]

The present invention has been made in consideration of the above-mentioned problems, and an object of the present invention is to provide a laser

annealing apparatus capable of reducing irradiation unevenness of laser light caused by a refraction phenomenon of laser light due to fluctuation (variation) in the temperature of inert gas.

[0008]

To achieve the above object, the laser annealing apparatus of the present invention apply the following means.

(1) According to one aspect of the present invention, there is provided a laser annealing apparatus that performs an annealing treatment on a workpiece to be processed by irradiating the workpiece with a laser light, characterized in that the apparatus includes a gas supply unit that supplies an inert gas to at least a laser irradiation area of the workpiece, and a gas temperature controller that controls the temperature of the inert gas, and the gas temperature controller controls the temperature of the inert gas supplied to the laser irradiation area so as to decrease the temperature difference between the temperature of the inert gas and the atmospheric temperature of a space that is disposed outside the supply area of the inert gas so as to surround an optical path of the laser light.

[0009]

According to the configuration of one embodiment of the present invention, the temperature of the inert gas supplied to the laser irradiation area is controlled by the gas temperature controller so as to approach the atmospheric temperature of a space (room) that is disposed outside the supply area of

the inert gas so as to surround the optical path of the laser light. With this configuration, since the temperature difference between the room and the inert gas decreases, the refraction phenomenon of the laser light is decreased, whereby irradiation unevenness is reduced. The temperature difference between the room and the inert gas is preferably as low as possible and is most preferably zero.

[0010]

(2) The gas supply unit includes a purge box which is disposed so as to face the surface of the workpiece and in which the inert gas is introduced, the purge box includes a transmission window that transmits the laser light so as to be introduced therein and an opening that passes the introduced laser light therethrough and blows the inside inert gas towards the workpiece, and the gas temperature controller controls the temperature of the inert gas at a position located further upstream than the purge box.

[0011]

According to the configuration of one embodiment of the present invention, since the purge box is disposed on the optical path of the laser light, although the laser light passes through the inert gas in the purge box during the annealing treatment, the temperature of the inert gas is controlled so as to approach the atmospheric temperature (temperature of the room) outside the purge box before the inert gas is

introduced into the purge box. Therefore, a refraction phenomenon of the laser light in the purge box is decreased, whereby irradiation unevenness is reduced.

[0012]

(3) The gas supply unit includes a parallel facing body that is disposed so as to face the surface of the workpiece in parallel and a purge unit that sprays the inert gas towards the workpiece so that the inert gas is supplied between the parallel facing body and the surface of the workpiece, and the gas temperature controller controls the temperature of the inert gas at a position that is located within the purge unit or located further upstream than the purge unit.

[0013]

According to the configuration, although the inert gas is sprayed from the purge unit towards the workpiece during the annealing treatment, and the laser light passes through the inert gas, the temperature of the inert gas is controlled so as to approach the atmospheric temperature of the space outside the purge unit before the inert gas is sprayed towards the workpiece. Therefore, a refraction phenomenon of the laser light in the supply area of the inert gas is decreased, whereby irradiation unevenness is reduced.

[0014]

(4) The gas supply unit includes a processing chamber which accommodates the workpiece and in which the

inert gas is introduced, and the gas temperature controller controls the temperature of the inert gas at a position located further upstream than the processing chamber.

[0015]

According to the configuration, although during the annealing treatment, the laser light passes through the inert gas inside the processing chamber, the temperature of the inert gas is controlled so as to approach the atmospheric temperature outside the processing chamber before the inert gas is introduced into the processing chamber. Therefore, a refraction phenomenon of the laser light in the processing chamber is decreased, whereby irradiation unevenness is reduced.

[0016]

According to embodiments of the present invention, it is possible to reduce irradiation unevenness of laser light caused by a refraction phenomenon of laser light due to fluctuation (variation) in the temperature of inert gas.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017]

Fig. 1 is a diagram illustrating an entire configuration of a laser annealing apparatus according to an embodiment of the present invention.

Fig. 2 is a diagram illustrating a first configuration example of a gas supply unit in the laser annealing apparatus according to the embodiment of the

present invention.

Fig. 3 is a diagram illustrating a second configuration example of a gas supply unit in the laser annealing apparatus according to the embodiment of the present invention.

Fig. 4 is a diagram illustrating a third configuration example of a gas supply unit in the laser annealing apparatus according to the embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0018]

Preferred embodiments of the present invention will be described below in detail with reference to the accompanying drawings. The same reference numerals are given to common portions in each of the drawings to avoid redundant description.

[0019]

Fig. 1 is a diagram illustrating an entire configuration of a laser annealing apparatus 1 according to an embodiment of the present invention. The laser annealing apparatus 1 includes, as its basic constituent elements, a laser light source 3 that emits laser light 2, a beam shaping optical system 4 that shapes the laser light 2 from the laser light source 3 into a desired beam shape, a reflecting mirror 5 that reflects the laser light 2 towards a workpiece to be processed 7, a condensing lens 6

that condenses the laser light 2 from the reflecting mirror 5 onto the surface of the workpiece 7, and a movable stage 9 that moves in a direction (direction indicated by arrow A in the figure) crossing the laser light 2 while carrying the workpiece 7.

[0020]

As the laser light source 3, an excimer laser, a solid-state laser, or a semiconductor laser can be used, for example. As examples of the solid-state laser, YAG, YLF, YVO_4, and the like can be used. The laser light 2 may be either pulse oscillated or continuously oscillated.

The beam shaping optical system 4 can be configured to shape the laser light 2 so as to have a linear or rectangular beam in sectional view on the surface of the workpiece 7, and in this case, can include a beam expander, a homogenizer, and the like as its constituent elements.

[0021]

The workpiece 7 includes a substrate 7a and an amorphous semiconductor film 7b formed thereon. The substrate 7a is a glass substrate or a semiconductor substrate. The amorphous semiconductor film 7b is an amorphous silicon film, for example.

[0022]

With the laser annealing apparatus 1 configured as above, the laser light 2 is emitted from the laser light source 3, and the laser light 2 is condensed into a linear

or rectangular beam by the beam shaping by the beam shaping optical system 4 and the condensing by the condensing lens 6 and irradiated onto the workpiece 7. In this state, the workpiece 7 is moved in the short-axis direction of the beam by the movable stage 9 so as to scan over the entire surface of the amorphous semiconductor film of the workpiece 7 at the laser irradiation portion. In this way, the amorphous semiconductor film 7b is crystallized. For example, the amorphous silicon film is changed to a polysilicon film.

[0023]

The beam shape of the laser light 2 irradiated onto the workpiece 7 is not limited to the linear or rectangular beam, and it is possible to effectively perform an annealing treatment on the workpiece 7 having a large area by scanning the laser light 2 condensed into a linear or rectangular beam in the short-axis direction thereof.

[0024]

The laser annealing apparatus 1 of the present invention further includes a gas supply unit 10 that supplies an inert gas G to at least a laser irradiation area of the workpiece 7 and a gas temperature controller 15 that controls the temperature of the inert gas G.

[0025]

As the inert gas G supplied from the gas supply unit 10, nitrogen, helium, neon, argon, krypton, xenon, radon, ununoctium, and the like can be used. The inert gas

G is introduced to the gas supply unit 10 through a gas pipe 14 from a gas tank or a gas cylinder which is provided outside a room R in which the laser annealing apparatus 1 is provided. For this reason, the temperature of the inert gas G is generally different from the temperature of the room R.

[0026]

The gas temperature controller 15 controls the temperature of the inert gas G supplied to the laser irradiation area so as to decrease the temperature difference between the temperature of the inert gas G and the atmospheric temperature of a space that is disposed outside the supply area of the inert gas G so as to surround the optical path of the laser light 2. The gas temperature controller 15 preferably has a function of both heating and cooling the inert gas G.

[0027]

Here, the space that is disposed outside the inert gas G so as to surround the optical path of the laser light 2 is generally the room R (for example, a cleanroom) in which the laser annealing apparatus 1 is provided, and the temperature thereof is the inside temperature of the room R. The temperature of the room R is detected by a temperature sensor 17 provided in the room R.

[0028]

The temperature detected by the temperature sensor 17 is converted into a temperature signal and transmitted

to a control unit 16. The control unit 16 controls the gas temperature controller 15 so that the temperature of the inert gas G approaches the temperature of the room R.

[0029]

According to the above-described configuration of the present invention, the temperature of the inert gas G supplied to the laser irradiation area is controlled by the gas temperature controller 15 so as to approach the atmospheric temperature of the space (room R) that is disposed outside the supply area of the inert gas G so as to surround the optical path of the laser light 2.

[0030]

For example, when the temperature of the room R is relatively low by an air conditioner, and the temperature of the inert gas G supplied from a gas tank provided at a different place is relatively high, the inert gas G is cooled by the gas temperature controller. Moreover, for example, when the temperature of the room R is relatively high by an air conditioner, and the temperature of the inert gas G supplied from a gas tank provided at a different place is relatively low, the inert gas G is heated by the gas temperature controller.

[0031]

In this way, since the temperature difference between the room R and the inert gas G is decreased, a refraction phenomenon of the laser light 2 is decreased, whereby irradiation unevenness is reduced. The temperature

difference between the room R and the inert gas G is preferably as low as possible and is most preferably zero. Therefore, it is preferable to control the temperature of the inert gas G so as to be the same as the temperature of the room R with the gas temperature controller 15.

[0032]

The gas supply unit 10 may employ various forms as long as it has a function of supplying the inert gas G to at least the laser irradiation area of the workpiece 7. Hereinafter, several configuration examples of the gas supply unit 10 will be described, and the present invention is not limited to these configuration examples.

[0033]

Fig. 2 is a diagram illustrating a gas supply unit 10A according to a first configuration example. In Fig. 2, the gas supply unit 10A includes a purge box 11 of which the lower surface in the figure is disposed so as to face the surface of the workpiece 7 and in which the inert gas G is introduced. The purge box 11 includes a transmission window 12 (for example, a glass window) that transmits the laser light 2 so as to be introduced therein and an opening 13 that passes the introduced laser light 2 therethrough and blows the inside inert gas G towards the workpiece 7.

[0034]

With this configuration, a purge area is formed by the inert gas G between the lower surface of the purge box 11 and the workpiece 7. For this reason, the lower surface

of the purge box 11 is preferably a flat surface that is parallel to the surface of the workpiece 7, and the distance between the lower surface of the purge box 11 and the workpiece 7 is preferably sufficiently small (for example, within 5 mm) within a range where they do not come into contact.

[0035]

The gas temperature controller 15 controls the temperature of the inert gas G at a position located further upstream than the purge box 11. In Fig. 2, the purge box 11 is connected to a gas pipe 14 for introducing the inert gas G into the purge box 11, and the gas temperature controller 15 is provided in the way of the gas pipe 14.

[0036]

As the gas temperature controller 15, for example, heat pumping heating-cooling equipment and electronic heating-cooling equipment using a Peltier device can be used. When the gas temperature controller 15 is configured as heating equipment only, it may be configured by a ribbon heater and a heating furnace. In this regard, the same statements can be applied to the second and third configuration examples.

[0037]

In the first configuration example, since the purge box 11 is disposed on the optical path of the laser light 2, although the laser light 2 passes through the

inert gas G in the purge box 11 during the annealing treatment, the temperature of the inert gas G is controlled so as to approach the atmospheric temperature (temperature of the room R) outside the purge box 11 before the inert gas G is introduced into the purge box 11. Therefore, the difference between the atmospheric temperature of the space surrounding the optical path of the laser light 2 and the temperature of the inert gas G inside the purge box 11 and in the purge area decreases, and a refraction phenomenon of the laser light 2 in the purge box 11 is decreased, whereby irradiation unevenness is reduced.

[0038]

Fig. 3 shows a gas supply unit 10B according to a second configuration example. In Fig. 3, the gas supply unit 10B includes a parallel facing body 18 of which the lower surface in the figure is disposed so as to face the surface of the workpiece 7 in parallel and a purge unit 22 that sprays the inert gas G towards the workpiece 7 so that the inert gas G is supplied between the parallel facing body 18 and the surface of the workpiece 7.

[0039]

With this configuration, a purge area is formed by the inert gas G between the lower surface of the parallel facing body 18 and the workpiece 7. For this reason, the lower surface of the parallel facing body 18 is preferably a flat surface that is parallel to the surface of the workpiece 7, and the distance between the lower surface of

the parallel facing body 18 and the workpiece 7 is preferably sufficiently small (for example, within 5 mm) within a range where they do not come into contact. Moreover, in the configuration example of Fig. 3, the parallel facing body 18 includes a transmission window 20 (for example, a glass window) which is formed on a bottom portion 19 that forms the lower surface facing the workpiece 7 so as to transmit the laser light 2.

[0040]

The purge unit 22 has a void structure in which the inert gas G is introduced and has a discharge opening 23 which is formed on the bottom portion thereof so as to blow the inert gas G towards the workpiece 7. In the configuration example of Fig. 3, the purge unit 22 is mounted on the side portion of the parallel facing body 18.

[0041]

In the configuration example of Fig. 3, the gas temperature controller 15 controls the temperature of the inert gas G at a position located further upstream than the purge unit 22. The purge unit 22 is connected to a gas pipe 14 for introducing the inert gas G into the purge unit 22, and the gas temperature controller 15 is provided in the way of the gas pipe 14. Alternatively, instead of this configuration, the gas temperature controller may be provided inside the purge unit 22 so as to heat or cool the inert gas G inside the purge unit 22.

[0042]

In the second configuration example, although the inert gas G is sprayed from the purge unit 22 towards the workpiece 7 during the annealing treatment, and the laser light 2 passes through the inert gas G, the temperature of the inert gas G is controlled so as to approach the atmospheric temperature of the space (a room R) outside the purge unit 22 before the inert gas G is sprayed towards the workpiece 7. Therefore, the difference between the atmospheric temperature of the space surrounding the optical path of the laser light 2 and the temperature of the inert gas G in the purge area decreases, and a refraction phenomenon of the laser light 2 in the supply area of the inert gas G is decreased, whereby irradiation unevenness is reduced.

[0043]

Fig. 4 shows a gas supply unit 10C according to a third configuration example. In Fig. 4, the gas supply unit 10C includes a processing chamber 25 which accommodates the workpiece 7 therein and in which the inert gas G is introduced. The processing chamber 25 is connected to an exhaust unit (not shown) for exhausting inside gas.

[0044]

In the processing chamber 25, a movable stage 9 is provided therein, and a transmission window 26 (for example, a glass window) is provided on the top portion thereof so as to transmit the laser light 2 therethrough.

Thus, the laser light 2 can be introduced into the processing chamber 25 through the transmission window 26 and irradiated onto the workpiece 7.

[0045]

The gas temperature controller 15 controls the temperature of the inert gas G at a position located further upstream than the processing chamber 25. The processing chamber 25 is connected to a gas pipe 14 for introducing the inert gas G into the processing chamber 25, and the gas temperature controller 15 is provided in the way of the gas pipe 14.

[0046]

In the third configuration example, by exhausting air inside the processing chamber 25 and introducing the inert gas G into the processing chamber 25, the inside of the processing chamber 25 is filled with the inert gas G. Although during the annealing treatment, the laser light 2 passes through the inert gas G inside the processing chamber 25, the temperature of the inert gas G is controlled so as to approach the atmospheric temperature of the space (a room R) outside the processing chamber 25 before the inert gas G is introduced into the processing chamber 25. Therefore, the difference between the atmospheric temperature of the space surrounding the optical path of the laser light 2 and the temperature of the inert gas G in the purge area decreases, and a refraction phenomenon of the laser light 2 in the

processing chamber 25 is decreased, whereby irradiation unevenness is reduced.

[0047]

While preferred embodiments of the present invention have been described and shown above, the disclosed embodiments have been provided for the purpose of illustration but the present invention is not limited to the disclosed embodiments. The scope of the invention is defined as set forth in the appended claims and is intended to encompass all modifications, changes and alterations which fall within the appended claims or the equivalents thereof.

CLAIMS

1. A laser annealing apparatus that performs an annealing treatment on a workpiece to be processed by irradiating the workpiece with a laser light, characterized in that the apparatus comprises

a gas supply unit that supplies an inert gas to at least a laser irradiation area of the workpiece, and

a gas temperature controller that controls the temperature of the inert gas, and

the gas temperature controller controls the temperature of the inert gas supplied to the laser irradiation area so as to decrease the temperature difference between the temperature of the inert gas and the atmospheric temperature of a space that is disposed outside the supply area of the inert gas so as to surround an optical path of the laser light.

2. The laser annealing apparatus according to claim 1,

wherein the gas supply unit includes a purge box which is disposed so as to face the surface of the workpiece and in which the inert gas is introduced,

wherein the purge box includes a transmission window that transmits the laser light so as to be introduced therein and an opening that passes the introduced laser light therethrough and blows the inside

inert gas towards the workpiece, and

wherein the gas temperature controller controls the temperature of the inert gas at a position located further upstream than the purge box.

3. The laser annealing apparatus according to claim 1,

wherein the gas supply unit includes a parallel facing body that is disposed so as to face the surface of the workpiece in parallel and a purge unit that sprays the inert gas towards the workpiece so that the inert gas is supplied between the parallel facing body and the surface of the workpiece, and

wherein the gas temperature controller controls the temperature of the inert gas at a position that is located within the purge unit or located further upstream than the purge unit.

4. The laser annealing apparatus according to claim 1,

wherein the gas supply unit includes a processing chamber which accommodates the workpiece and in which the inert gas is introduced, and

wherein the gas temperature controller controls the temperature of the inert gas at a position located further upstream than the processing chamber.

LASER ANNEALING APPARATUS

ABSTRACT

Provided is a laser annealing apparatus capable of reducing irradiation unevenness of laser light caused by a refraction phenomenon of laser light due to fluctuation in the temperature of inert gas.

A laser annealing apparatus 1 includes a gas supply unit 10 for supplying inert gas G to at least a laser irradiation area of a workpiece 7 to be processed, and a gas temperature controller 15 for regulating the temperature of the inert gas G. The gas temperature controller 15 controls the temperature of the inert gas G supplied to the laser irradiation area so as to decrease the temperature difference between the temperature of the inert gas G and the atmospheric temperature of a space (a room R) that is disposed outside the supply area of the inert gas so as to surround the optical path of the laser light.

Fig. 1