Specification

[Title of the Invention] LASER ANNEALING METHOD AND ANNEALING DEVICE FOR SEMICONDUCTOR FILM

[Technical Field]

[0001]

The present invention relates to a method and a device for manufacturing poly-crystalline or single-crystalline semiconductor films used for thin-film transistors used as pixel switches and drive circuits for liquid crystal displays and organic EL displays.

[Background Art]

[0002]

For the thin-film transistors used as the pixel switches and drive circuits for the liquid crystal displays and the organic EL displays, laser annealing employing laser light is used as a part of a manufacturing method in a low temperature process. This method irradiates the laser light on a non-single-crystal semiconductor film formed on a substrate, thereby locally heating and melting the semiconductor film, and then, crystallizes the semiconductor film into polycrystals or single-crystals in a subsequent cooling process. The crystallized semiconductor film presents high mobility of carriers, resulting in an increased performance of the thin film transistors. For the irradiation of the laser light, it is necessary to carry out uniform processing on the semiconductor film, and thus, control is generally performed for maintaining a constant laser light output so that the

irradiated laser light has stable irradiation energy.

[0003]

However, when an oscillation condition of a laser oscillator changes, or a pulse waveform changes due to a degradation of a laser gas while the laser light output is still constant, there are cases that constant crystallization properties are not be obtained. FIG. 3 shows changes in a laser pulse waveform when laser pulse energy is changed, and it is appreciated that a profile itself of the pulse waveform changes as the laser pulse energy fluctuates.

Therefore, conventionally, there has been generally used a method of detecting the laser light using a power meter or a photodiode, thereby controlling the laser light output and the like so that an energy integral value of the laser light waveform remains constant.

Moreover, in addition to this, there has been proposed a pulsed gas laser oscillation device which acquires a ratio between multiple maximal values in a pulse waveform of laser light, and, when this ratio exceeds a predetermined value, controls at least either one of a quantity of an excitation gas infused into a sealed container for laser gas or a voltage value supplied to a charging/discharging circuit from the power supply (refer to patent document 1).

[Related Art Document]

[Patent Document]

[0004]

[Patent Document 1] Japanese Laid-Open Patent Publication (Kokai)

[Summary of the Invention]

[Problems to be solved by the Invention]

[0005]

The conventional methods and devices are configured as described above, and thus pose the following problems.

1. When a halogen gas is infused as the laser gas, the laser oscillation is unstable until the laser gas composition ratio is stabilized.

2. As a halogen gas composition ratio increases, pulse energy stability decreases

3. "Keeping the ratio between the maximal values within the predetermined range" requires a certain time period.

4. "Keeping the ratio between the maximal values within the predetermined range" and a stable oscillation presenting a small energy fluctuation in the laser are opposite to each other.

5. Due to influence of beam divergence and the like, an original pulse waveform of the laser oscillator and a pulse waveform irradiated on an object to be irradiated are different from each other.

[0006]

The present invention is devised to solve the above-described problems of the conventional methods and devices, and embodiments of the present invention seek to provide a laser annealing method and an annealing device for semiconductor film which maintain the stability of the laser light energy contributing to crystallization, and provide semiconductor films having

constant crystalline properties.

[Means for Solving the Problems]

[0007]

According to an aspect of the present invention, there is provided a laser annealing method for semiconductor film of irradiating pulsed laser light of an excimer laser light on a silicon film of a non-single-crystal semiconductor film to apply annealing and thus to crystallize the non-single-crystal semiconductor film, wherein the pulse laser light irradiating on the non-single-crystal semiconductor film has a first peak as a maximum peak height of a temporal pulse profile of the pulse laser light, and a laser pulse energy of the pulsed laser light to be outputted from a laser oscillator and/or a laser pulse energy of the pulsed laser light after outputted from the laser oscillator is adjusted so that the maximum peak height of the temporal pulse profile being changed due to a change of an oscillation condition of the laser oscillator maintains a predetermined prescribed maximum peak height composed of a maximum peak height of a temporal pulse profile obtained with an initially set irradiation energy density optimum for crystallization.

The laser annealing method for semiconductor film of the first embodiment of the present invention is a laser annealing method for semiconductor film of irradiating pulsed laser light on a non-single-crystal semiconductor film to apply annealing, wherein energy control for the pulsed laser light is performed so that a maximum peak height of a pulse waveform of the laser light maintains a predetermined height.

[0008]

According to a laser annealing method for semiconductor film of a second embodiment of the present invention, in the first embodiment of the present invention, the maximum peak height of the pulse waveform of the laser light may be measured, and an output energy of the pulsed laser light and/or an energy of the pulsed laser light after the output may be adjusted so that the maximum peak height reaches the predetermined height.

[0009]

According to embodiments of the present invention, crystalline properties of the semiconductor film on which the laser light is irradiated are constant by maintaining the maximum peak height of the laser light waveform at the predetermined height. It should be noted that the pulse width of the pulse waveform is generally equal to or less than 1000 nanoseconds, and is preferably equal to or less than 500 nanoseconds. However, embodiments of the present invention are not limited to a case having a specific pulse width. Moreover,

the predetermined height of the pulse waveform can be properly selected, and is set so that the crystalline properties are constant and excellent. Generally, a range is defined for the predetermined height, and the control is performed so that the maximum peak height of the pulse waveform is kept within this range.

[0010]

FIG. 4 shows the maximum peak height optimum for crystallization and an energy density (measured by a laser power meter) optimum for the crystallization at an irradiated location of laser with respect to the laser pulse energy. As apparent from the figure, the optimum energy density is different for different laser pulse energies, and it is thus appreciated that, even when the control of maintaining a constant integral value of the pulse waveform is performed, the optimum condition for the crystallization cannot be maintained if the laser pulse energy fluctuates. On the other hand, as for the maximum peak height, the optimum maximum peak height is approximately constant for different laser pulse energies, and it is thus possible to maintain the optimum conditions for the crystallization by maintaining a constant maximum peak height of the waveform even if the laser pulse energy fluctuates. Whether the condition is optimum for the crystallization can be determined by the observation of crystal grain diameter using an electron microscope, or the like.

[0011]

Moreover, FIG. 5 shows a relationship between the pulse energy (measurement value by a power meter or energy meter), a pulse area (integral value of pulse waveform), and the maximum peak height. As

apparent from the figure, the pulse energy and the maximum peak height are not in proportional relationship, and thus, it is not possible to maintain a state optimum for the crystallization even if the pulse energy is maintained constant.

[0012]

According to the second embodiment of the present invention, it is possible to properly maintain the maximum peak height of the pulse waveform at the predetermined height by adjusting the output energy or the energy of the laser light while the maximum peak height is being measured. The method of adjusting the output energy may include an adjustment of the quantity of the infused excitation gas of the laser oscillator and an adjustment of a discharge voltage value of the laser oscillator. Moreover, the adjustment of the energy of the pulsed laser light after the output may be carried out by means of a variable attenuator which can adjust the attenuation rate of the pulsed laser light output from the laser oscillator. The variable attenuator may be any attenuator which can properly change the attenuation rate of the laser light, and is not limited to a specific one in the present invention,.

[0013]

According to the laser annealing method for semiconductor film of a third embodiment of the present invention, in the first or second embodiment of the present invention, the non-single-crystal semiconductor film may be a silicon film.

[0014]

According to the laser annealing method for semiconductor film of a fourth embodiment of the present invention, in any of the first to third embodiments of

the present invention, the pulsed laser light may be excimer laser light.

[0015]

According to the laser annealing method for semiconductor film of a fifth embodiment of the present invention, in any of first to fourth embodiments of the present invention, the maximum peak height of the pulse waveform may be measured on a pulse waveform of the laser light irradiated on the non-single-crystal semiconductor film.

[0016]

The laser annealing device for semiconductor film of a sixth embodiment of the present invention, includes: a laser oscillator that outputs pulsed laser light; an optical system that leads the pulsed laser light to a non-single-crystal semiconductor film; a maximum peak height measurement unit that measures a maximum peak height of the pulsed laser light; and a control unit that receives a measured result by the maximum peak height measurement unit, and controls an energy of the pulsed laser light of the laser oscillator so that the maximum peak height reaches a predetermined height.

[0017]

The laser annealing device for semiconductor film of a seventh embodiment of the present invention, includes: a laser oscillator that outputs pulsed laser light; a variable attenuator that adjusts an attenuation rate of the pulsed laser light; an optical system that leads the pulsed laser light to a non-single-crystal semiconductor film; a maximum peak height measurement unit that measures a maximum peak height of the pulsed laser light; and a control unit that receives a measured result by the

maximum peak height measurement unit, and controls the attenuation rate of the variable attenuator so that the maximum peak height maintains a predetermined height.

[0018]

The control unit may control both the energy of the pulsed laser light in the laser oscillator and the attenuation rate of the variable attenuator.

[0019]

According to the laser annealing device for semiconductor film of an eighth embodiment of the present invention, in the sixth or seventh embodiment of the present invention, the maximum peak height measurement unit may include: a beam splitter that is provided on an optical path of the pulsed laser light; a pulse waveform detection unit that detects a waveform of a part of the pulsed laser light split by the beam splitter; and a maximum peak height determination unit that determines the maximum peak height of the pulse waveform detected by the pulse waveform detection unit.

[Effects of the Invention]

[0020]

As described before, according to the laser annealing method for semiconductor film of the present invention, in the laser annealing method for semiconductor film of irradiating pulsed laser light on a non-single-crystal semiconductor film to apply annealing, the energy control for the pulsed laser light is performed so that the maximum peak height of the pulse waveform of the laser light maintains the predetermined height, and the following effects are thus provided.

1. The energy density of the laser irradiation is controlled according to the maximum peak height of the pulse waveform having a high correlation with the crystalline properties, and the constant crystalline properties are thus always obtained.

2. Even when the pulse waveform changes due to a change of oscillation conditions of the laser oscillator, the constant crystalline properties are always obtained.

3. When the pulse waveform changes due to a degradation of the laser gas while the output (W) is constant, the energy density of the laser irradiation is controlled according to the maximum peak height of the pulse waveform having a high correlation with the crystalline properties, and the constant crystalline properties are thus always obtained.

[Brief Description of the Drawings]

[0021]

[FIG. 1] A drawing schematically showing a laser annealing device according to an embodiment of the present invention.

[FIG. 2] A flow chart showing steps of maintaining a state optimal for crystallization.

[FIG. 3] A chart showing a change in a laser pulse waveform when laser pulse energy is changed.

[FIG. 4] A chart showing an energy density and the maximum peak height that are optimal for the crystallization with respect to the laser pulse energy.

[FIG. 5] A chart showing a relationship of a pulse energy density and

the maximum peak height with the laser pulse energy.

[Modes for Carrying out the Invention]

[0022]

A description will now be given of an embodiment of the present invention referring to accompanying drawings.

A laser annealing device includes a laser oscillator 1 for outputting gas laser light, and the laser oscillator 1 can adjust a laser light output by adjusting the quantity of a gas to be infused and a discharge voltage. As the laser oscillator 1, an excimer laser oscillator LSX315C (wavelength: 308 nm, repetition rate: 300 Hz) from Coherent, Inc. can be used, for example.

[0023]

A variable attenuator 2 is disposed on an optical path along which laser light 10 outputted from the laser oscillator 1 is emitted. The variable attenuator 2 is constructed by an attenuator optical element the transmittance of which changes according to an incident angle of the laser light, thereby enabling adjustment of an attenuation rate of the laser light transmitting through the variable attenuator 2. The adjustment of the attenuation rate on the variable attenuator 2 can be carried out by a variable-attenuator control unit 3, and the variable-attenuator control unit 3 may be constructed by a CPU, a program operating the CPU, and the like, for example.

[0024]

An optical system 4 in which an optical member such as a homegenizer is arrange is provided on an optical path on an emission side of

the variable attenuator 2, and the laser light 10 is shaped into a line beam having a length of 465 mm and a width of 0.4 mm, for example, by the optical system 4.

A part of the laser light 10 led by the optical system 4 is extracted by a beam splitter 5, and a major part thereof transmits through the beam splitter 5, and is irradiated on an object to be processed 6. As the object to be processed 6, an a-Si (amorphous Si) film having a thickness 50 nm, for example, is considered.

[0025]

Laser light 10a extracted from the beam splitter 5 is input to a pulse waveform detection means 7. The pulse waveform detection means 7 detects a pulse waveform of the laser light 10a, and corresponds to a pulse waveform detection unit according to the present invention. For example, as the pulse waveform detection means 7, a biplanar phototube from Hamamatsu Photonics (type R1193U-52) is used.

A result detected by the pulse waveform detection means 7 is output to a control unit 8. The control unit 8 is constructed by a CPU, a program for operating the CPU, a memory unit storing data relating to a predetermined maximum peak height of the pulse waveform in a non-volatile manner, and the like. The control unit 8 determines the maximum peak height of the waveform from the detected result by the pulse waveform detection means 7. The control unit 8 thus has a function as a maximum peak height determination unit, and cooperates with the pulse waveform detection means 7 to construct a maximum peak height measurement unit according to the present invention. The control unit 8

can control the output of the laser oscillator 1, and also issues a control command to the variable-attenuator control unit 3.

[0026]

A description will now be given of an operation of the laser annealing device.

The laser light 10 is output from the laser oscillator 1 according to an output set initially. Oscillation energy of the laser oscillator 1 is controlled by a built-in energy meter. A value of the energy meter is proportional to an integral value of the pulse waveform.

[0027]

The laser light 10 reaches the variable attenuator 2. The variable attenuator 2 is controlled to transmit the laser light 10 at an attenuation rate initially set by the variable-attenuator control unit 3. The variable attenuator 2 sets an irradiation energy density optimum for crystallizing the object to be processed 6.

The laser light attenuated by the predetermined attenuation rate is shaped into the belt shape by the optical system 4, and reaches the beam splitter 5. The laser light which transmits through the beam splitter 5 is irradiated on the object to be processed 6 to apply the laser annealing thereto. The laser light 10a split by the beam splitter 5 reaches the pulse waveform detection means 7, and the information on the detected pulse waveform is output to the control unit 8.

[0028]

A description will now be given of control steps in the control unit 8 based on FIG. 2.

First, in a step 1, the pulse waveform is detected, and the detected result is output to the control unit 8 as described before (step s1).

The control unit 8 determines, from the detected pulse waveform, the maximum peak height in the waveform (step s2). A first peak in the waveform is generally the maximum peak as shown in FIG. 3, and the maximum peak height can thus be recognized by determining this first peak height.

[0029]

The control unit 8 then reads the data on a predetermined range of the maximum peak height stored in the memory unit, and compares it with the determined (detected) maximum peak height (step s3). It should be noted that the predetermine range of the maximum peak height is stored in advance in the memory unit. For the predetermined range of the maximum peak height, different data may be set according to the type of the object to be processed 6 and the like.

If the detected maximum peak height is within the predetermined range of the maximum peak height in the above comparison ("YES" in the step s3), it is considered that the present laser light 10 has the maximum peak height optimum for the crystallization, and the detection of the laser light waveform continues (to the step s1). The detection of the laser waveform carried out repeatedly may be continuous or intermittent with a predetermined interval.

[0030]

If the detected maximum peak height is not within the predetermined range ("NO" in the step s3), the laser output is to be adjusted.

The output adjustment of the laser oscillator 1 is carried out by adjusting the discharge voltage. If the detected maximum peak height is higher than the predetermined range, the control unit 8 adjusts the discharge voltage of the laser oscillator 1 so that the output is decreased, and the maximum peak height thus falls in the predetermined range, and, on the other hand, if the detected maximum peak height is lower than the predetermined range, the control unit 8 adjusts the laser oscillator 1 so that the output is increased, and the maximum peak height thus falls in the predetermined range. A quantity of the adjustment may be determined based on the quantity of a deviation of the detected maximum peak height from the predetermined range.

After the adjustment, the waveform of the laser light is continuously detected (to the step s1) until the laser irradiation processing is finished ("YES" in a step s5).

[0031]

As described above, even when the output of the laser light fluctuates, by maintaining the maximum peak height of the waveform at the predetermined value, the laser annealing can be carried out in the state optimum for the crystallization regardless of the shape of the pulse waveform, thereby always obtaining constant crystals.

Though, in the above control steps, the maximum peak height of the pulse waveform is adjusted by the output adjustment in the laser oscillator 1, the maximum peak height of the pulse waveform may be adjusted by adjusting the attenuation rate in the variable attenuator 2, or the maximum peak height of the pulse waveform may be adjusted by both the output

adjustment in the laser oscillator 1 and the adjustment of the attenuation rate in the variable attenuator 2.

Though the present invention is described based on the above embodiment, the present invention is not limited to the contents of the description, and may be properly changed within the scope of the present invention.

[Description of the Numerals]

[0032]

1 Laser oscillator

2 Variable attenuator

3 Variable-attenuator control unit

4 Optical system

5 Beam splitter

6 Object to be irradiated

7 Pulse waveform detection means

8 Control unit

Claims

[Claim 1]

A laser annealing method for semiconductor film of irradiating pulsed laser light of an excimer laser light on a silicon film of a non-single-crystal semiconductor film to apply annealing and thus to crystallize the non-single-crystal semiconductor film, wherein the pulse laser light irradiating on the non-single-crystal semiconductor film has a first peak as a maximum peak height of a temporal pulse profile of the pulse laser light, and a laser pulse energy of the pulsed laser light to be outputted from a laser oscillator and/or a laser pulse energy of the pulsed laser light after outputted from the laser oscillator is adjusted so that the maximum peak height of the temporal pulse profile being changed due to a change of an oscillation condition of the laser oscillator maintains a predetermined prescribed maximum peak height composed of a maximum peak height of a temporal pulse profile obtained with an initially set irradiation energy density optimum for crystallization.