DESCRIPTION

TITLE OF INVENTION: METHOD FOR MANUFACTURING CRYSTALLINE SEMICONDUCTOR AND LASER ANNEALING APPARATUS

TECHNICAL FIELD

[0001]

The present invention relates to a method for manufacturing a crystalline semiconductor and a laser annealing apparatus, which are suitably used for manufacturing a polycrystalline or monocrystalline semiconductor film of a thin film transistor used in a pixel switch or drive circuit for liquid crystal display or organic EL display.

BACKGROUND ART

[0002]

In such a thin film transistor used in the pixel switch or drive circuit for liquid crystal display or organic EL (Electro-Luminescence) display, laser annealing using laser is performed as part of a manufacturing method of low-temperature process thereof. This method comprises locally heating and melting a non-monocrystalline semiconductor film formed on a substrate by laser irradiation, and crystallizing the semiconductor thin film into polycrystal or monocrystal in a cooling step thereof. The thus-crystallized semiconductor thin film can attain higher performance of the thin film transistor since the mobility of carrier is enhanced.

In the above-mentioned laser irradiation, it is necessary to perform a homogenous treatment on the semiconductor film. Therefore, control for keeping laser power constant is generally performed so that the laser being irradiated has stable irradiation energy, and control for keeping pulse energy constant is performed in pulsed lasers.

[0003]

By the way, excimer gas laser which is frequently used in the above-mentioned pulsed laser oscillates a laser beam by electric discharge

method. In high-power excimer laser, a plurality of discharges are caused by residual voltage after a first discharge by high voltage, and a laser beam having a plurality of peaks is consequently generated. At that time, the second-to-last peaks can have characteristics differed from the first peak. Therefore, there is proposed a pulsed laser oscillation device, which is configured to stabilize characteristics of crystallized silicon by determining a ratio of a plurality of maximal values in a pulse waveform of pulsed laser and keeping this ratio within a predetermined range (refer to Patent Literature 1).

In this pulsed laser oscillation device, the waveform changed with time of a pulsed laser beam is set so that it includes two or more peak groups, and the peak value of the pulsed laser beam in the second peak group is in the range of 0.37 to 0.47 relative to the pulsed laser beam in the first peak group.

CITATION LIST

PATENT LITERATURE

[0004]

PATENT LITERATURE 1: Japanese Patent Application Laid-Open No. 2001-338892

SUMMARY OF INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0005]

In the above-mentioned apparatus shown in Patent Literature 1, the characteristics of crystallized silicon are held constant by keeping the peak ratio in a stable range as described above. However, even if the peak ratio is stabilized in such a range, the crystallization and activation of a silicon thin film are not necessarily homogenized in the surface of the silicon thin film.

As a result of further examinations on the above-mentioned peak ratio, the present inventors found that the value itself of the peak ratio more

significantly contributes to the homogenization of crystallization characteristics than the stabilization of the peak ratio does, and achieved the present invention.

MEANS FOR SOLVING BY THE INVENTION

[0006]

Namely, a method for manufacturing a crystalline semiconductor of the present invention comprises: crystallizing an amorphous semiconductor by irradiating the amorphous semiconductor with pulsed laser, in which the pulsed laser has a plurality of peak groups in one pulse in temporal intensity change, and a first peak group having a maximum height, of the peak groups, and a second peak group which appears subsequently satisfy a relationship of (second peak group)/(first peak group)≤0.35 in terms of peak intensity value when the pulsed laser is irradiated on the amorphous semiconductor.

[0007]

A laser annealing apparatus of the present invention comprises: a laser oscillator which outputs pulsed laser; an optical system which guides the pulsed laser to an amorphous semiconductor; and a moving device which relatively moves the amorphous semiconductor so that the pulsed laser is irradiated to the amorphous semiconductor with scanning, in which the laser oscillator outputs the pulsed laser so that the pulsed laser has a plurality of peaks in one pulse in temporal intensity change, and a first peak group having a maximum height, of the peak groups, and a second peak group which appears subsequently satisfy a relationship of (second peak group)/(first peak group)≤0.35 in terms of peak intensity value.

[0008]

In the present invention, the above-mentioned peak intensity ratio satisfies the above-mentioned relationship, whereby uniform crystallization characteristics can be secured when the amorphous semiconductor irradiated with the pulsed laser is crystallized. If this ratio exceeds 0.35, the characteristics of the crystallized semiconductor tend to vary.

One peak group may have a plurality of peaks, and the peak intensity in the peak group can be shown by the maximum height in the peak group. General excimer laser roughly has two peak groups, in which a first peak group having a relatively large height appears at first, and a second peak group having a relatively small height appears subsequently after going through a minimal value at which the intensity is largely reduced (about a fraction of the maximum height). In the present invention, three or more peak groups may appear in one pulse.

The one pulse may be outputted from one laser oscillator, or may be constituted by superposing pulses output from two or more laser oscillators.

[0009]

The pulsed laser is required to satisfy the above-mentioned peak intensity ratio when outputted from the laser oscillator. When a plurality of peak groups exist in one pulse in temporal intensity change, in general, the heights of the respective peak groups cannot be separately adjusted. Therefore, the pulsed laser is adjusted so that it satisfies at least the above-mentioned peak intensity ratio when outputted from the laser oscillator. The maximum height of the pulsed laser can be reduced due to a change in laser waveform which is caused by passage of the pulsed laser through an optical system or the like. In this case, the above-mentioned peak intensity ratio tends to increase since the intensity of the first peak group is reduced. Thus, in a case such that the above-mentioned peak intensity ratio is changed by an optical path, the peak intensity ratio of the pulsed laser being outputted from the laser oscillator is set to a value of 0.35 or less considering the above-mentioned change (a further small value) so that the peak intensity ratio of the pulsed laser in the irradiation on the amorphous semiconductor satisfies the above-mentioned condition.

[0010]

The power of the pulsed laser is set preferably to 700 mJ or more in terms of pulse energy, further preferably to 850 mJ or more. Although the peak intensity ratio tends to reduce when the power of pulse energy is small, the adjustment range of an attenuator which is disposed in the optical path

to adjust the transmissivity of the laser is reduced at low pulse energy.

[0011]

In the present invention, an amorphous silicon thin film formed on a substrate is a preferable target as the amorphous semiconductor. The material of the substrate is not particularly limited in the present invention although a glass substrate is generally used as the substrate, and the substrate may be formed from other materials. The thickness of the amorphous silicon thin film is not particularly limited in the present invention although the amorphous silicon thin film is generally formed in a thickness of 40 to 100 nm.

[0012]

As the pulsed laser, excimer laser of wavelength 308 nm is preferably used. However, the type of pulsed lasers is never limited to this in the present invention.

ADVANTAGES OF THE INVENTION

[0013]

As described above, according to the present invention, a homogeneous crystalline semiconductor can be effectively obtained since, when the amorphous semiconductor is crystallized by irradiating the amorphous semiconductor with pulsed laser, the pulsed laser is adjusted so that it has a plurality of peak groups in one pulse in temporal intensity change, and a first peak group having a maximum height, of the peak groups, and a second peak group which appears subsequently satisfy a relationship of (second peak group)/(first peak group)$\leq$0.35 in terms of peak intensity value when the pulsed laser is irradiated on the amorphous semiconductor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014]

[Fig. 1] Fig. 1 is a schematic view showing a laser annealing apparatus according to one embodiment of the present invention.

[Fig. 2] Fig. 2 is a view showing pulse waveforms of pulsed lasers in an example of the present invention.

[Fig. 3] Fig. 3 is a view showing SEM photographic images at each energy density in the example of the present invention.

[Fig. 4] Fig. 4 is a conceptual view showing polycrystalline silicon thin films with irradiation unevenness in the example of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

[0015]

One embodiment of the present invention will be described based on Fig. 1.

In a method for manufacturing a crystalline film of this embodiment, a substrate 8 used for a flat panel display TFT device is taken as a target, and an amorphous silicon thin film 8a is formed on the substrate 8 as an amorphous film. The amorphous silicon thin film 8a is formed on the upper side of the substrate 8 by an ordinary method, and subjected to dehydrogenation treatment.

In the present invention, however, the types of the substrate as the target and the amorphous film formed thereon are never limited to the above.

[0016]

Fig. 1 is an excimer laser annealing treatment apparatus 1 used in the method for manufacturing a crystalline film of the one embodiment of the present invention, and the excimer laser annealing treatment apparatus 1 corresponds to the laser annealing apparatus of the present invention.

In the excimer laser annealing treatment apparatus 1, an excimer laser oscillator 2 which outputs pulsed laser having a wavelength of 308 nm, a frequency of 1 to 600 Hz, and a pulse width (FWHM: full width at half maximum) of 20 to 50 ns is installed on a vibration-free base 6, and the excimer laser oscillator 2 includes a control circuit 2a which generates pulse signals.

[0017]

The pulsed laser outputted from the excimer laser oscillator 2 has two peak groups A, B in one pulse in temporal change as shown in Fig. 2, in which the peak intensity a of the first peak group A having a maximum height and the peak intensity b of the second peak group B satisfy a condition in which b/a is 0.35 or less. Since only the second-to-last peaks cannot be formed separately from the first peak and the second-to-last peaks cannot be controlled, it is necessary to output pulsed laser in which the intensities of the second-to-last peaks are reduced. The setting of this pulsed laser waveform can be performed through design of a laser oscillation circuit, setting of energy in the laser oscillator, adjustment of the gas mixing ratio of excimer gas laser or the like.

The above-mentioned excimer laser oscillator 2 corresponds to the laser oscillator of the present invention.

[0018]

An attenuator 3 is disposed on the output side of the excimer laser oscillator 2, and an optical fiber 5 is connected to the output side of the attenuator 3 through a coupler 4. An optical system 7 including condenser lenses 70a, 70b, and beam homogenizers 71a, 71b disposed between the condenser lenses 70a, 70b is connected to the transmission destination of the optical fiber 5. The optical system 7 may further include a proper optical member such as a mirror. The content of the optical system is not particularly limited in the present invention, and may be constituted by proper optical members. In the optical system 7, the pulsed laser can be shaped into a proper beam in addition to being guided.

[0019]

A substrate mount 9 on which the substrate 8 is placed is installed in the outputting direction of the optical system 7. The optical system 7 is set so as to shape the pulsed laser into a rectangular or line beam in terms of irradiated surface shape. The substrate mount 9 is movable along the surface direction (XY direction) of the substrate mount 9, and is provided with a moving device 10 for rapidly moving the substrate mount 9 along the

surface direction.

[0020]

A crystallization method of an amorphous silicon thin film using the above-mentioned excimer laser annealing treatment apparatus 1 will be then described.

The substrate 8 with the amorphous silicon thin film 8a formed on the upper side is placed on the substrate mount 9.

In the control circuit 2a, a pulse signal is generated so that pulsed laser having a preset pulse frequency (1 to 600 Hz), a pulse width (FWHM) 20 to 50 ns and the above-mentioned pulse energy is generated, and the pulsed laser of wavelength 308 nm is output from the excimer laser oscillator 2 according to the pulse signal.

[0021]

The pulsed laser output from the excimer laser oscillator 2 reaches the attenuator 3, and is attenuated at a predetermined attenuation rate by being passed through it. The attenuation rate is set so that the pulsed laser has a predetermined energy density in a processing surface. The attenuator 3 may vary the attenuation rate.

The pulsed laser adjusted in energy density is transmitted and guided into the optical system 7 by the optical fiber 5. In the optical system 7, the pulsed laser is shaped into a rectangular or line beam having a short axis width of 1.0 mm or less by the condenser lenses 70a, 70b, the beam homogenizers 71a, 71b and the like as described, and irradiated to the substrate 8 at the predetermined energy density in the processing surface. The pulsed laser has two peak groups in temporal change similarly to when it is outputted, and the peak intensity ratio calculated by (peak intensity of second peak group)/(peak intensity of first peak group) is 0.35 or less in the processing surface.

[0022]

The above-mentioned substrate mount 9 is moved in the short axis width direction of the line beam along the surface of the amorphous silicon thin film 8a by the moving device 10, and as a result, the above-mentioned

pulsed laser is relatively irradiated with scanning in a wide range of the surface of the amorphous silicon thin film 8a.

[0023]

Only the amorphous silicon thin film 8a on the substrate 8 is heated by the irradiation with the above-mentioned pulsed laser beam, and rapidly polycrystallized.

The crystalline thin film obtained by the above-mentioned irradiation has homogenous and high-quality crystallinity with an average crystal grain diameter of about 350 nm. The above-mentioned crystalline thin film can be suitably used for organic EL displays. The purpose of use is not limited to the above in the present invention, and the crystalline thin film can be used for other liquid crystal displays and as electronic materials.

The relative scanning of the pulsed laser beam may be performed by moving the optical system to which the pulsed laser beam is guided, as well as by relatively moving the substrate mount in the above-mentioned embodiment.

EXAMPLE 1

[0024]

An example of the present invention will be then described.

Fig. 2 shows pulse waveforms of pulsed laser outputted with varied powers (1050 mJ, 950 mJ, 850 mJ) by use of the same laser oscillator. The waveforms were measured at a position corresponding to the amorphous silicon thin film 8a on the substrate 8, and the intensities thereof are shown as relative values.

The pulse waveform has a first peak group A and a second peak group B which appears subsequently. When the power of the pulsed laser is increased (1050 mJ), not only the maximum height of the first peak group but also the height of the second peak group are increased as a consequence, and the ratio of b/a is 0.418, wherein a is the peak intensity of the first peak group and b is the peak intensity of the second peak group. When the power of the pulsed laser is smaller than this (950 mJ), the above-mentioned

ratio is still 0.374 although it is reduced.

[0025]

In this way, when pulsed laser with a peak intensity ratio exceeding 0.35 is irradiated to the silicon thin film, the silicon thin film is melted twice due to relatively high intensity of the second peak group. Namely, although silicon is crystallized when the silicon thin film is melted and changed from a liquid to a solid by the first peak, the coagulated silicon thin film is remelted if the intensity of the second peak is high, causing recrystallization. This phenomenon is caused with dispersion in the silicon thin film, impairing the homogeneity of crystallization.

As is apparent from Fig. 2, the above-mentioned ratio is reduced to 0.35 or less when the power of the pulsed laser is further reduced (850 mJ). The silicon thin film is thus homogenously crystallized.

[0026]

Then, pulsed lasers with the above-mentioned peak intensity ratios being 0.374 (comparative example) and 0.341 (inventive example) were irradiated to silicon thin films at energy densities (E/D) shown in Fig. 3 to crystallize the films. SEM photographic images (magnification 5,000; photographic image substitute for drawing) of the resulting polycrystalline silicon thin films are shown in Fig. 3.

Although the crystallinity is varied depending on the magnitude of the energy density being irradiated on the substrate, it is found that resulting crystals are more homogenous in a polycrystalline silicon thin film irradiated with laser pulse with the intensity of the second peak being low (inventive example) than in a polycrystalline silicon thin film irradiated with laser pulse with the intensity of the second peak being high (comparative example).

[0027]

Further, irradiation unevenness was visually observed by irradiating white light to the above-mentioned test materials from an oblique direction while changing the angle. Observation results about an inventive example with energy density of 337 mJ/cm^2 and a comparative example with energy

density of 333 mJ/cm^2 were shown in Fig. 4. As is apparent from Fig. 4, irradiation unevenness was observed in the comparative example although no irradiation unevenness was observed regardless of the irradiation angle in the inventive example in which homogenous crystallization was attained. No irradiation unevenness was observed in inventive materials other than that shown, and irradiation unevenness was observed in comparative examples other than that shown.

[0028]

Although the present invention has been described above based on the embodiment, the present invention is never limited to the content of the embodiment and can be properly changed without departing from the scope of the present invention.

DESCRIPTION OF SYMBOLS

[0029]

1. Excimer laser annealing treatment apparatus
2. Excimer laser oscillator
3. Attenuator
7. Optical system
70a. Condenser lens
70b. Condenser lens
71a. Beam homogenizer
71b. Beam homogenizer
8. Substrate
8a. Amorphous silicon thin film
9. Substrate mount
10. Moving device

WHAT IS CLAIMED IS

1. A method for manufacturing a crystalline semiconductor, comprising:

crystallizing an amorphous semiconductor by irradiating the amorphous semiconductor with pulsed laser, in which the pulsed laser has a plurality of peak groups in one pulse in temporal intensity change, and a first peak group having a maximum height, of the peak groups, and a second peak group which appears subsequently satisfy a relationship of (second peak group)/(first peak group)≤0.35 in terms of peak intensity value when the pulsed laser is irradiated on the amorphous semiconductor.

2. The method for manufacturing the crystalline semiconductor according to claim 1, wherein the amorphous semiconductor is an amorphous silicon thin film formed on a substrate.

3. A laser annealing apparatus comprising:

a laser oscillator which outputs pulsed laser;

an optical system which guides the pulsed laser to an amorphous semiconductor; and

a moving device which relatively moves the amorphous semiconductor so that the pulsed laser is irradiated to the amorphous semiconductor with scanning, in which

the laser oscillator outputs the pulsed laser so that the pulsed laser has a plurality of peak groups in one pulse in temporal intensity change, and a first peak group having a maximum height, of the peak groups, and a second peak group which appears subsequently satisfy a relationship of (second peak group)/(first peak group)≤0.35 in terms of peak intensity value.

4. The laser annealing apparatus according to claim 3, wherein the pulsed laser satisfies the relationship {(second peak group)/(first peak group)≤0.35} when it is irradiated on the amorphous semiconductor.