DESCRIPTION

TITLE OF INVENTION

METHOD FOR MANUFACTURING CRYSTALLINE SEMICONDUCTOR FILM

TECHNICAL FIELD

[0001]

The present invention relates to a method for manufacturing a crystalline semiconductor film, where a pulse laser with a line beam shape is shifted while irradiating a non-single crystalline semiconductor film a plurality of times (overlapped irradiation) to perform crystallization.

BACKGROUND ART

[0002]

Thin film transistors used for TVs or PC displays are generally formed of amorphous (non-crystalline) silicon (hereinafter referred to as a-silicon), but if silicon is crystallized (hereinafter referred to as p-silicon) by some means, it can be used with dramatically improved performance as TFT. At present, excimer laser annealing technologies as a Si crystalline process at low temperatures have already been put into use and have been used popularly in applications for small-sized displays such as for mobile phones. Furthermore, practical applications, such as to large-sized displays, is being sought.

In this laser annealing method, a non-single crystalline semiconductor film is irradiated by an excimer laser with high pulse energy, so that the semiconductor having absorbed light energy becomes a molten or semi-molten state and then crystallized when rapidly cooled and solidified. During this process, a pulse laser formed of a line beam shape is irradiated by relatively scanning in the direction of the shorter axis for processing a wide area. In general, pulse laser is scanned by shifting a mount table on which a single crystalline semiconductor film is mounted.

[0003]

In the above pulse laser scanning, a pulse laser is shifted in the scanning direction at a predetermined pitch such that the pulse laser is irradiated a plurality of times (overlap irradiation) to same locations of a non-single crystalline semiconductor film (refer to, for example, Patent Literature 1). This enables a semiconductor film having a large size to be subjected to a laser annealing process. Patent Literature 1 discloses that the size S of the channel region in the scanning direction of the pulse laser and the scanning pitch P of the pulse laser roughly satisfy $S = nP$ (where n is an integer except zero) to cause crystal distribution on the crystalline Si film to form a periodically varying pattern in the scanning direction of the pulse laser, so that the crystalline Si film on the channel region of each thin film transistor may form a crystalline distribution pattern with a same periodical variation, because crystalline ununiformity (variation) associated with laser sequential operation may cause variation among elements.

[0004]

In conventional laser annealing processes using a line beam, the beam width in the scanning direction of the pulse laser is fixed to about 0.35 to 0.4 mm and the substrate feed amount per pulse is set to about 3% to 8% of the beam width. In order to obtain uniform performance among a plurality of thin film transistors, it is considered necessary to increase as much as possible the number of laser irradiation.

For semiconductor film for LCD, for example, the overlap ratio is set to 92 to 95% (the number of irradiation: 12 to 20 times, scanning pitch: 32 to 20 μm) and, for OLED semiconductor film, the overlap ratio is set to 93.8 to 97% (the number of irradiation: 16 to 33 times, scanning pitch: 25 to 12 μm).

CITATION LIST

PATENT LITERATURE

[0005]

Patent Literature 1: Japanese Patent Application Laid-Open No. Hei 10-163495

SUMMARY OF INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0006]

The inventors of the present invention, however, carried out a study and found that, although the smaller the scanning pitch value the larger the number of laser irradiation, actually, the crystal grain size is saturated without growing when the number of irradiation becomes a certain number or higher, for example, about eight times of irradiation in a certain condition. In other words, an unnecessary increase in the number of irradiation will increase crystallization processing time without effective use of laser output.

At the same time, an unnecessary increase of the beam width will cause lower processing efficiency when processing a semiconductor film of a larger size, because the energy of the laser pulse is constant, consequently requiring a shorter line beam length to obtain a certain energy density.

[0007]

The present invention is made in view of the above situation and embodiments of the present invention seek to provide a method for manufacturing a crystalline semiconductor film, which provides an effective laser annealing process by appropriately determining the number of irradiation and the pulse width of the laser pulse.

MEANS FOR SOLVING BY THE INVENTION

[0008]

An aspect of the present invention provides a method for manufacturing a crystalline semiconductor film, in which a pulse laser of a line beam shape having a beam width of less than or equal to 500 μm is irradiated shifting each pulse and thereby overlapped by a number n of irradiations while relatively scanning a non-single crystalline semiconductor film to perform crystallization, the method characterized in that the pulse laser has a plateau region (beam width of "a") of a uniform intensity in cross-sectional shapes of the beam in a scanning direction, the pulse laser has an irradiation pulse energy density E that is lower than an irradiation pulse energy density that causes microcrystallization on the non-single crystalline semiconductor film by irradiating the pulse laser and at which a growth in crystal grain size is saturated by a plurality of times of the irradiations of the pulse laser, the number n of

irradiation of the pulse laser is more than or equal to (n0-1) where n0 is the number of irradiation at which growth in crystal grain size is saturated by the irradiation of the pulse laser with the irradiation pulse energy density E, and a shift amount c per pulse in the scanning direction of the pulse laser is less than or equal to b/2 where b is the width (less than or equal to 1 mm), in the scanning direction, of a channel region of a transistor formed with semiconductor film crystallized by irradiation of the pulse laser.

[0009]

The pulse laser, as mentioned above, has a plateau region (beam width of "a") of a uniform intensity in the cross-sectional shape of the beam in the scanning direction. The plateau region is represented by an area having more than or equal to 90% of the maximum energy intensity.

The number of irradiation is defined as n0 at which growth in crystal grain size is saturated by the irradiation of the pulse laser with the irradiation pulse energy density E. The irradiation pulse energy density E is a value that is lower than an irradiation pulse energy density that causes microcrystallization on the non-single crystalline semiconductor film by irradiating the pulse laser. Whether or not microcrystallization may occur can be determined with, such as using electron microscope.

When the irradiation pulse energy density is more than a value that causes microcrystallization, the crystal grain size will become extremely small and the electron mobility as a semiconductor will be about one tenth.

The meaning that growth in crystal grain size is saturated by the irradiation of the pulse laser with the irradiation pulse energy density E, indicates a state in which each grain size is uniform and the grain size no longer increases even though the number of irradiation increases.

Furthermore, when the number of laser irradiation does not reach (n0-1), the crystal grain size does not grow sufficiently, producing a mixture of crystals with different grain sizes, causing variation in electron mobility. Preferably, it is more than or equal to n0 for the same reason.

At the same time, the number n of laser irradiation is preferably less than or equal to $3 \cdot n0$. When it exceeds $3 \cdot n0$, the productivity is extremely

lowered. More preferably, it is less than or equal to $2 \cdot n0$ for the same reason.

[0010]

The scanning pitch of the pulse laser, i.e., the shift amount c per pulse, is less than or equal to b/2, where b is the width, in the scanning direction, of a channel region of a transistor formed on semiconductor film crystallized by irradiation of the pulse laser. By this, the number of seams of the laser pulse appearing on each channel region will be two or three or more, reducing variation in transistor performance. On the other hand, when the shift amount c is larger than b/2 and less than or equal to b, the number of seams on a channel region will be one or two. When the shift amount c is larger than b, the number of seams on a channel region will be zero or one, causing large variation in transistor performance on channel regions.

[0011]

The beam width "a" of the pulse laser can be expressed as $a = n \cdot c$, using a number n of irradiation of the laser and a shift amount c per pulse. The beam width is preferably less than or equal to 500 μm. With a constant energy density, a too large beam width will cause lower processing efficiency, because the beam length in the direction of the long axis of the pulse laser becomes smaller, resulting in a smaller processing area per scan.

[0012]

The width of channel region in the scanning direction of the pulse laser is preferably less than or equal to 1 mm. Reduction in width of transistor domains, i.e., reduction of transistor, will shorten the time for electron to flow in transistors, thus improving signal processing speed, providing thin film semiconductor with high performance.

[0013]

Semiconductors targeted by the present invention are not limited to a specific material, but Si is one that is preferable. For the pulse laser, excimer laser can be one that is preferable.

EFFECTS OF THE INVENTION

[0014]

As mentioned above, an aspect of the present invention provides a method for manufacturing a crystalline semiconductor film, in which a pulse laser of a line beam shape having a beam width of less than or equal to 500 μm is irradiated shifting each pulse and thereby overlapped by a number n of irradiations while relatively scanning a non-single crystalline semiconductor film to perform crystallization, the method characterized in that the pulse laser has a plateau region (beam width of "a") of a uniform intensity in cross-sectional shapes of the beam in a scanning direction, the pulse laser has an irradiation pulse energy density E that is lower than an irradiation pulse energy density that causes microcrystallization on the non-single crystalline semiconductor film by irradiating the pulse laser and at which a growth in crystal grain size is saturated by a plurality of times of the irradiations of the pulse laser, the number n of irradiation of the pulse laser is more than or equal to (n0-1) where n0 is the number of irradiation at which growth in crystal grain size is saturated by the irradiation of the pulse laser with the irradiation pulse energy density E, and a shift amount c per pulse in the scanning direction of the pulse laser is less than or equal to b/2 where b is the width (less than or equal to 1 mm), in the scanning direction, of a channel region of a transistor formed with the semiconductor film crystallized by irradiation of the pulse laser. Therefore, it may provide an effective laser annealing process with an appropriate number of irradiation of a pulse laser and a shift amount per pulse. In addition, a proper beam width of the pulse laser may provide sufficient line beam length, providing an effect that may enable the process to be much effective.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015]

[Fig. 1] Fig. 1 shows a pulse laser irradiation state to a non-single crystalline semiconductor film according to an embodiment of the present invention.

[Fig. 2] Fig. 2 shows a cross-sectional shape of the beam of a pulse laser in the scanning direction according to the same.

[Fig. 3] Fig. 3 shows the relationship between the irradiation pulse energy density of a pulse laser and the crystal grain size by pulse laser

irradiation according to the same.

[Fig. 4] Fig. 4 shows the relationship between the number of irradiation and the crystal grain size when the pulse laser has certain irradiation pulse energy densities according to the same.

[Fig. 5] Fig. 5 shows occurrence states of beam seams in relationships between the shift amount per pulse and the width of the channel region according to the same.

[Fig. 6] Fig. 6 is a photograph, as a replacement of a drawing, of crystallized semiconductor according to an example of the present invention.

[Fig. 7] Fig. 7 is a graph showing the variation of the grain size with respect to the number of irradiation according to the same.

EMBODIMENT FOR CARRYING OUT THE INVENTION

[0016]

An embodiment of the present invention is now explained as follows.

Fig. 1 shows a pulse laser 3, which is an excimer laser with a line beam shape, irradiating a substrate mounted on a moving table 1. The substrate is formed with a non-single crystalline semiconductor film 2 such as Si amorphous. The pulse laser 3, which has a line beam length L and a beam width "a", is irradiated on the non-single crystalline semiconductor film 2 at a predetermined pitch and number of irradiation while scanning with the pulse laser 3 by shifting the moving table 1 at a predetermined pitch.

Fig. 2 shows a cross-sectional shape of the beam of the pulse laser 3 in the scanning direction. It has a plateau region, width of which is represented by a beam width "a", having an energy intensity of more than or equal to 90% with respect to the maximum energy intensity.

[0017]

The pulse laser 3 is set to an irradiation pulse energy density E at which the non-single crystalline semiconductor film 2 will not become microcrystalline when the non-single crystalline semiconductor film 2 is irradiated.

Fig. 3 shows the relationship between the irradiation pulse energy density and the crystal grain size by laser pulse irradiation. The crystal grain size becomes larger as the irradiation pulse energy density increases in a region in which the irradiation pulse energy density is low. The crystal grain size rapidly increases, when the irradiation pulse energy density becomes larger than, for example, an irradiation pulse energy density E1 on the way. When the irradiation pulse energy density becomes larger to a certain degree, on the other hand, the crystal grain size grows little as the irradiation pulse energy density become larger than it, and the crystal grain size rapidly become smaller forming microcrystals when it exceeds a certain irradiation pulse energy density E2. Therefore, the above irradiation pulse energy density E can be expressed as $E \leq E2$.

[0018]

With the irradiation pulse energy density set to the above value E to irradiate the non-single crystalline semiconductor film 2, growth in crystal grain size will be saturated, even though the number of irradiation is set to a certain times or more. The saturation in growth in crystal grain size is determined with SEM photographs.

Fig. 4 shows the relationship of the crystal grain size with respect to the number of irradiation when the irradiation pulse energy density E is set to the irradiation pulse energy density E1 or the irradiation pulse energy density E2. In either irradiation pulse energy density, the crystal grain size becomes larger as the number of irradiation increases until a certain number of irradiation, but the number of irradiation reaches a certain number, the crystal grain size is saturated without growing more than it. The above number of irradiation is expressed as the number n0 of irradiation of the present invention.

The number n of an actual irradiation will be set to more than or equal to (n0-1) and less than or equal to $3 \cdot n0$ with respect to the above number n0 of irradiation. This enables the non-single crystalline semiconductor film 2 to be crystallized effectively and efficiently.

[0019]

On the crystallized semiconductor film crystallized by the irradiation of the pulse laser, thin film semiconductors are formed at predetermined intervals. Each thin film semiconductor has a predetermined width b of the channel region, and the intervals are preferably set to less than or equal to 1 mm.

Fig. 5 shows an assumed state of the array of thin film semiconductor 10 on the non-single crystalline semiconductor film 2. Each thin film semiconductor 10 has a source 11, a drain 12 and a channel part 13 located between the source and the drain, and the width of the channel part 13 in the scanning direction of the pulse laser is a width b of the channel region. When the pulse laser 3 is irradiated to the non-single crystalline semiconductor film 2 and shifted by a scanning pitch (shift amount per pulse) c, beam seams 3a will appear on the crystallized semiconductor film in response to the shift per pulse.

[0020]

Fig. 5(a) shows an occurrence state of beam seams 3a when the shift amount c per pulse is larger than the width b of the channel region. In this example, the beam seams 3a will not be positioned or appear one on a channel part 13, causing a larger performance variation of the thin film semiconductor 10.

Fig. 5(b) shows an occurrence state of beam seams 3a when the shift amount c per pulse is larger than a half of the width b of the channel region. In this example, the beam seams 3a will appear one or two on a channel part 13, which may reduce the performance variation of the thin film semiconductor 10 but will not sufficiently reduce it.

Fig. 5(c), which is provided by the present invention, shows an occurrence state of beam seams 3a when the shift amount c per pulse is smaller than a half of the width b of the channel region. In this example, the beam seams 3a will appear two or three on channel parts 13, which will effectively reduce the performance variation of thin film semiconductor 10.

[0021]

The beam width "a" is expressed as $a=n \cdot c$ when the number of

irradiation is set to n times with the shift amount c per pulse. The above setting enables the shift amount c per pulse to be set smaller and the number of irradiation not to be larger than a necessary number of times for making good crystallization. As a result, the beam width can be set smaller, for example, to less than or equal to 500 μm, allowing the beam length to be larger so that a non-single crystalline semiconductor film of a large size can be efficiently processed.

Example 1

[0022]

An example of the present invention is explained below.

A pulse laser was irradiated to Si amorphous of a thickness of 50 nm as a non-single crystalline semiconductor film by varying the number of irradiation in the following conditions:

Excimer laser: LSX315C / wavelength of 308 nm, frequency of 300 Hz

Beam size: beam length of 500 mm by beam width of 0.13 mm

The beam width is a plateau region with more than or equal to 90% of the maximum energy intensity.

Scanning pitch: 32.5 μm to 6.5 μm

Irradiation pulse energy density: 320 mJ/cm^2

The width of the channel region: 40 μm

[0023]

With the pulse laser, the irradiation pulse energy density is equal to or less than an irradiation pulse energy density that will cause microcrystals, where the crystal grain size gradually grows until the number of irradiation reaches four to eight, but the growth in crystal grain size is saturated when the number of irradiation reaches eight or larger.

[0024]

Areas irradiated with the pulse laser at a predetermined number of irradiation was observed with SEM photographs, which are shown in Fig. 6. As shown in Fig. 6, good crystallization was obtained when the number of irradiation is eight, but little increase in crystal grain size was observed even

when the number of irradiation was increased to 12, 16 and 20.

Fig. 7 shows variation of the crystal grain size in response to the number of irradiation, in which the crystal grain size grows as the number of irradiation increases until the number of irradiation reaches eight. No growth in crystal grain size was observed when the number of irradiation is eight or larger.

DESCRIPTION OF SYMBOLS

[0025]

1	Moving table
2	Non-single crystalline semiconductor film
3	Pulse laser
3a	Beam seam
10	Thin film semiconductor
11	Source
12	Drain
13	Channel part

CLAIMS

1. A method for manufacturing a crystalline semiconductor film, in which a pulse laser of a line beam shape having a beam width of less than or equal to 500μm is irradiated shifting each pulse and thereby overlapped by a number n of irradiations while relatively scanning, on a non-single crystalline semiconductor film to perform crystallization, the method characterized in that:

the pulse laser has a plateau region of a uniform intensity in cross-sectional shapes of the beam in a scanning direction;

the pulse laser has an irradiation pulse energy density E that is lower than an irradiation pulse energy density that causes microcrystallization on the non-single crystalline semiconductor film by irradiating the pulse laser and at which a growth in crystal grain size is saturated by a plurality of times of the irradiations of the pulse laser;

the number n of irradiation of the pulse laser is more than or equal to (n0-1) where n0 is the number of irradiation at which growth in crystal grain size is saturated by the irradiation of the pulse laser with the irradiation pulse energy density E; and

a shift amount c per pulse in the scanning direction of the pulse laser is less than or equal to b/2 where b is the width (less than or equal to 1 mm), in the scanning direction, of a channel region of a transistor formed with semiconductor film crystallized by irradiation of the pulse laser.

2. The method for manufacturing a crystalline semiconductor film according to claim 1, characterized in that the number n of irradiation of the pulse laser is more than or equal to (n0-1) and less than or equal to 3·n0.

3. The method for manufacturing a crystalline semiconductor film according to any one of the preceding claims, characterized in that the non-single crystalline semiconductor is Si.

4. The method for manufacturing a crystalline semiconductor film according to any one of the preceding claims, characterized in that the pulse laser is an excimer laser.

METHOD FOR MANUFACTURING CRYSTALLINE SEMICONDUCTOR FILM

ABSTRACT

The present invention provides crystallization of a non-single crystalline semiconductor film, when the semiconductor film is annealed by laser, with an appropriate scanning pitch and number of irradiation.

Provided is a method for manufacturing a crystalline semiconductor film, in which a pulse laser of a line beam shape is irradiated to perform crystallization, the method characterized in that the pulse laser has a plateau region (beam width of "a") of a uniform intensity in cross-sectional shapes of the beam in a scanning direction, the pulse laser has an irradiation pulse energy density E that is lower than an irradiation pulse energy density that causes microcrystallization on the non-single crystalline semiconductor film, the number n of irradiation of the pulse laser is more than or equal to (n0-1) where n0 is the number of irradiation at which growth in crystal grain size is saturated by the irradiation by the pulse laser with the irradiation pulse energy density E, and a shift amount c in the scanning direction of the pulse laser is less than or equal to b/2 where b is the width of a channel region of a transistor formed with the semiconductor film crystallized by irradiation of the pulse laser.

Fig. 1