Description

Title of Invention: MANUFACTURING METHOD OF CRYSTALLINE SEMICONDUCTOR FILM

Technical Field

[0001]

The present invention relates to a manufacturing method of a crystalline semiconductor film, in which a pulse laser shaped into a line beam shape is radiated a plurality of times (radiated in an overlapped manner) on a non-single crystalline semiconductor film while the pulse laser is made to move.

Background Art

[0002]

While, typically, a thin film transistor used in a TV set or a display of a PC is comprised of amorphous (non-crystalline) silicon (hereinafter, referred to as "a-silicon"), by utilizing silicon obtained by crystalizing the silicon through some means (hereinafter, referred to as "p-silicon"), it is possible to dramatically improve a function as a TFT. Currently, an excimer laser annealing technique has been already put into practical use as Si crystallization process at low temperature, and this technique is frequently utilized for application in a small display such as a mobile phone,

and is further put into practical use for a display with a large screen.

In this laser annealing technique, an excimer laser having high pulse energy is radiated on a non-single crystalline semiconductor film, thereby a semiconductor absorbing light energy is put into a molten state or a semi-molten state, and crystallization occurs while the semiconductor is cooled down rapidly and coagulated. At this time, to process a larger area, a pulse laser shaped in a line beam shape is radiated while scanning is relatively performed in a short axis direction. Normally, scanning is performed with the pulse laser by moving a stage on which a single crystalline semiconductor film is placed.

[0003]

During the scanning with the above-described pulse laser, the pulse laser is moved in a scanning direction at a predetermined pitch so that the pulse laser is radiated to the same position on the non-single crystalline semiconductor film a plurality of times (radiated in an overlapped manner) (see, for example, Patent Literature 1). By this means, it becomes possible to perform laser annealing processing on a large semiconductor film. It should be noted that Patent Literature 1 discloses a solution to a problem that ununiformity (variation) of crystalline properties due to sequential scanning with the laser causes variation

between devices. To solve the problem, Patent Literature 1 discloses setting a size S of a channel region in the scanning direction of the pulse laser and the scanning pitch P of the pulse laser so as to satisfy substantially S=nP (where n is an integer except 0), and so that crystalline distribution of a crystalline Si film has a pattern which periodically changes in the scanning direction of a pulse laser light, and the crystalline Si films in channel regions of the respective thin film transistors have the same periodical change in the pattern of the crystalline distribution.

Citation List

Patent Literature

[0004]

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

Summary of Invention

Technical Problem

[0005]

However, controlling a scanning pitch to be an integral multiple in accordance with a size of a channel region is difficult in terms of accuracy, and, if it is tried to realize an apparatus which performs scanning at high accuracy, the apparatus cost rises drastically.

If a width of the beam in a short axis direction is sufficiently large, it is possible to increase the scanning pitch, and minimize irradiation with a beam edge for each pulse in the channel region. However, in this state, both transistors in which the channel region is irradiated with a beam edge once and transistors in which the channel region is not irradiated with a beam edge (zero times) exist, and properties vary between the transistors.

[0006]

Therefore, by reducing the scanning pitch to always irradiate the channel region with a beam edge for each pulse a predetermined number of times, it is possible to reduce crystalline variation. By this means, there is no case where both transistors which are irradiated with the above-described edge and transistors which are irradiated with an edge portion exist. Further, because a difference in the number of times can be suppressed to one, variation of the properties can be drastically reduced compared to a case where some transistors are irradiated with an edge and the others are not.

[0007]

Because, in a linear region on the semiconductor irradiated with such an edge portion, it is considered that movement of a carrier in a channel is affected, a scanning direction of the pulse laser is set so as to be positioned along a direction in which a linear edge is

orthogonal to a channel width, that is, a moving direction of the carrier within the channel. By this means, favorable properties of movement of the carrier can be expected also in the channel region which is not irradiated with the beam edge.

[0008]

However, in the above-described scanning direction, because the transistors having a channel width equal to or smaller than a channel length (channel width/channel length is 1 or less) have a relatively smaller channel width than the channel width of the transistors (channel width/channel length is over 1), both a linear region which is irradiated with the above-described edge and a region which is not irradiated with an edge exist in a width direction in the channel region. Due to this, there is a problem that ununiformity of resistance, or the like, occurs in the channel width direction and ununiformity of carrier movement occurs, which affects the transistor characteristics. Further, there is also a problem that ununiformity in the width direction occurs because part of a source and a drain is irradiated with the edge.

[0009]

The present invention has been made in view of the above-described circumstances, and an object of the present invention is to provide a manufacturing method of a crystalline semiconductor film, which can perform

favorable crystallization while reducing variation in characteristics of a transistor without the need of scanning with a pulse laser at high accuracy.

Solution to Problem

[0010]

That is, a first aspect of a manufacturing method of a crystalline semiconductor film of the present invention is a method in which scanning is relatively performed on a non-single crystalline semiconductor film with a pulse laser shaped into a line beam shape having a flat portion in a shape of a beam cross-section in a beam short axis direction, the pulse laser having a beam short axis width of 100 to 500 μm, so that the pulse laser is made to move for each pulse, and the non-single crystalline semiconductor film is irradiated a number of times of irradiation n in an overlapped manner, a channel width of a transistor formed on the semiconductor film is set at b (100 μm or less), and the pulse laser has irradiation pulse energy density E lower than irradiation pulse energy density at which fine crystallization occurs at the non-single crystalline semiconductor film by irradiation with the pulse laser and at which crystal grain size growth is saturated by a plurality of times of irradiation, the number of times of irradiation n with the pulse laser is (n0-1) or greater where n0 is a number of times of irradiation when the crystal grain size

growth is saturated by irradiation with the pulse laser at the irradiation pulse energy density E, and a scanning direction of the pulse laser is set as a channel length direction of the transistor, and an amount of movement c for each pulse is set at less than b.

[0011]

A second aspect of the manufacturing method of the crystalline semiconductor film of the present invention is a method in the first aspect of the present invention, in which the number of times of irradiation n with the pulse laser is (n0-1) or greater and 3·n0 or less.

[0012]

A third aspect of the manufacturing method of the crystalline semiconductor film of the present invention is a method in the first or the second aspect of the present invention, in which the amount of movement is less than b/2.

[0013]

A fourth aspect of the manufacturing method of the crystalline semiconductor film of the present invention is a method in any of the first to the third aspects of the present invention, in which the amount of movement is 5 μm or greater.

[0014]

A fifth aspect of the manufacturing method of the crystalline semiconductor film of the present invention is a method in any of the first to the fourth aspects of

the present invention, in which a ratio of a channel width and a channel length of the transistor (channel width/channel length) is 1 or less.

[0015]

A sixth aspect of the manufacturing method of the crystalline semiconductor film of the present invention is a method in any of the first to the fifth aspects of the present invention, in which the non-single crystalline semiconductor is Si.

[0016]

A seventh aspect of the manufacturing method of the present invention is a method in any of the first to the sixth aspects of the present invention, in which the pulse laser is an excimer laser.

[0017]

As described above, the pulse laser has a flat portion (beam width a) where intensity is flat, in a shape of a cross-section in a short axis direction. By averaging the intensity at the flat portion, it is possible to calculate maximum energy intensity of the pulse laser. Further, normally, steepness portions where intensity gradually decreases toward the outside of the flat portion are provided at both sides of the flat portion.

[0018]

A minimum number of times of irradiation required for saturating crystal grain size growth by irradiation

with the pulse laser having the irradiation pulse energy density E is set at n0. It should be noted that the irradiation pulse energy density E is set at a value lower than irradiation pulse energy density at which fine crystallization occurs at the non-single crystalline semiconductor film by irradiation with the pulse laser. Whether or not fine crystallization occurs can be determined using an electron micrograph, or the like.

If the irradiation pulse energy density is set at a value greater than a value at which fine crystallization occurs, a crystal grain size becomes extremely small, and electron mobility as a semiconductor decreases to be approximately one-tenth.

Further, a state where the crystal grain size growth is saturated by irradiation with the pulse laser having the irradiation pulse energy density E means a state where individual grain sizes become the same, and the grain size does not increase even if the number of times of irradiation is increased.

Still further, if the number of times of irradiation with the laser does not reach (n0-1), the crystal grain size does not grow sufficiently, crystals having different grain sizes are mixed, which causes variation in electron mobility. For the same reason, the number of times of irradiation with the laser is preferably n0 or greater.

Further, the number of times of irradiation n with the laser is preferably 3·n0 or less. If the number of times of irradiation n with the laser exceeds 3·n0, productivity significantly decreases. Further, for the same reason, the number of times of irradiation n with the laser is more preferably 2·n0 or less.

[0019]

If the channel length of the transistor on the semiconductor film on which the pulse laser is radiated is set at b, the scanning pitch of the pulse laser, that is, the amount of movement c for each pulse is set at less than b. By this means, because the number of joints of the laser pulse appearing in each channel region is one, two or more, it is possible to reduce variation in characteristics of the transistor. Meanwhile, if the amount of movement c is less than b/2, the number of joints in the channel region is n or (n+1) or more (where n is an integer of two or greater). Because the number of joints in a channel region where the amount of movement c is greater than b is zero or one, the characteristics of the transistor in the channel region widely vary.

[0020]

It should be noted that a transistor in which a channel region is formed upon irradiation with the pulse laser, or a transistor in which a channel region is

formed after irradiation with the pulse laser, can be used as the transistor.

Further, it should be noted that a channel length of a semiconductor film to which the present invention is directed is 100 μm or less. While the channel length is not particularly limited in the present invention if the channel length falls within this range, the channel length is preferably 6 to 40 μm.

[0021]

The beam width (a) of the pulse laser can be expressed with $a=n \cdot c$ with the number of times of irradiation n with the laser and the amount of movement c for each pulse. This beam width is preferably 100 to 500 μm. If the beam width is too large, when the energy density is fixed, because the beam length in a long axis direction of the pulse laser becomes small, an area processed through scanning at one time becomes small, which results in degradation of processing efficiency. Further, if the beam width is less than 100 μm, the scanning pitch becomes small, which results in degradation of production efficiency.

It should be noted that while the amount of movement for each pulse is not particularly limited to a specific amount in the present invention, the amount of movement is, for example, preferably, 5 μm or greater.

[0022]

While a material of a semiconductor to be processed in the present invention is not limited to a particular material, the material is, for example, preferably, Si. Further, an excimer laser can be preferably used as the pulse laser. The manufacturing method according to the present invention includes a method in which characteristics of a crystalline semiconductor film are modified through single crystallization, in addition to a method in which an amorphous semiconductor film is crystalized.

Advantageous Effects of Invention

[0023]

As described above, according to the manufacturing method of the crystalline semiconductor film of the present invention, because scanning is relatively performed on a non-single crystalline semiconductor film with a pulse laser shaped into a line beam shape having a flat portion in a shape of a beam cross-section in a beam short axis direction, the pulse beam having a beam short axis width of 100 to 500 μm, so that the pulse laser is made to move for each pulse, and the non-single crystalline semiconductor film is irradiated a number of times of irradiation n in an overlapped manner, a channel length of a transistor formed on the semiconductor film is set at b (100 μm or less), and the pulse laser has irradiation pulse energy density E lower than irradiation

pulse energy density at which fine crystallization of the non-single crystalline semiconductor film occurs by irradiation with the pulse laser and at which crystal grain size growth is saturated by a plurality of times of irradiation, the number of times of irradiation n with the pulse laser is (n0-1) or greater where n0 is a number of times of irradiation when the crystal grain size growth is saturated by irradiation with the pulse laser at the irradiation pulse energy density E, and a scanning direction of the pulse laser is set as a channel length direction of the transistor, and an amount of movement c for each pulse is set at less than b, it is possible to efficiently perform laser annealing processing with an appropriate number of times of irradiation with the pulse laser and an appropriate amount of movement for each pulse. Further, it is possible to reduce variation in transistor characteristics due to irradiation of a beam edge.

Brief Description of Drawings

[0024]

[Figure 1] Figure 1 illustrates a state where a pulse laser is radiated on a non-single crystalline semiconductor film according to one embodiment of the present invention.

[Figure 2] Figure 2 illustrates a shape of a beam cross-section in a scanning direction of the pulse laser.

[Figure 3] Figure 3 illustrates relationship between irradiation pulse energy density of the pulse laser and a crystal grain size by irradiation with the pulse laser.

[Figure 4] Figure 4 illustrates relationship between the number of times of irradiation and the crystal grain size when the pulse laser has predetermined irradiation pulse energy density.

[Figure 5] Figure 5 illustrates a state where a beam joint occurs in relationship between an amount of movement for each pulse and a channel region width.

[Figure 6] Figure 6 is a photograph which is substitute for the drawing illustrating a crystalline semiconductor according to one embodiment of the present invention.

[Figure 7] Figure 7 is a graph illustrating relationship of change in a grain size with respect to the number of times of irradiation.

[0025]

One embodiment of the present invention will be described below.

Figure 1 illustrates a state where a pulse laser 3 comprised of an excimer laser shaped into a line beam shape is radiated on a substrate placed on a moving stage 1. On the substrate, for example, a non-single crystalline semiconductor film 2 such as amorphous Si having a film thickness of 35 to 55 nm is formed. It should be noted that the film thickness is not limited to the above-described range in the present invention.

The pulse laser 3 has a line beam length L and a beam width a, and, by moving the moving stage 1 at a predetermined pitch, scanning is performed with the pulse laser 3, and the non-single crystalline semiconductor film 2 is irradiated at a predetermined pitch a predetermined number of times of irradiation. It should be noted that scanning can be performed in other ways if scanning is relatively performed with the pulse laser 3 on the non-single crystalline semiconductor film 2, that is, scanning can be performed by moving the non-single crystalline semiconductor film 2 as described above, or scanning can be performed by moving the pulse laser 3 side. Further, it is also possible to combine these ways.

Figure 2 illustrates a shape of a beam cross-section in a scanning direction of the pulse laser 3. The shape of the beam cross-section has a high intensity region where energy intensity is 96% or higher of maximum energy intensity, and most of the high intensity region is a flat portion. A width of the flat portion is indicated as the beam width a.

[0026]

Further, the pulse laser 3 is set to have irradiation pulse energy density (E) at which fine crystallization does not occur at the non-single crystalline semiconductor film 2 when the pulse laser 3 is radiated on the non-single crystalline semiconductor film 2. The irradiation pulse energy density is, for

example, 320 to 420 mJ/cm^2. However, the irradiation pulse energy density is not limited to a particular range in the present invention.

Figure 3 illustrates relationship between the irradiation pulse energy density and a crystal grain size by irradiation with the laser pulse. In a region where the irradiation pulse energy density is low, the crystal grain size becomes larger in accordance with increase of the irradiation pulse energy density. For example, if the irradiation pulse energy density becomes larger than the irradiation pulse energy density E1 which is in the course of increase, the crystal grain size becomes drastically large. Meanwhile, if the irradiation pulse energy density becomes large to some extent, even if the irradiation pulse energy density increases, the crystal grain size does not substantially increase, and if the irradiation pulse energy density exceeds given irradiation pulse energy density E2, the crystal grain size becomes drastically small, and fine crystallization occurs. Therefore, the above-described irradiation pulse energy density E can be expressed with $E \leq E2$.

[0027]

When the irradiation pulse energy density is set at the above-described value E, and the laser pulse is radiated on the non-single crystalline semiconductor film 2, even if the number of times of irradiation is set at a given number or more, crystal grain size growth is

saturated. Saturation of the crystal grain size growth is determined using a SEM photograph.

Figure 4 illustrates relationship of the crystal grain size with respect to the number of times of irradiation when the irradiation pulse energy density E is set at the above-described irradiation pulse energy density E1 or the irradiation pulse energy density E2. In both cases of the irradiation pulse energy density, while the crystal grain size becomes larger in accordance with increase in the number of times of irradiation until reaching the given number of times of irradiation, the crystal grain size growth does not proceed further and is saturated when the number of times of irradiation reaches the given number of times of irradiation. This number of times of irradiation is expressed at the number of times of irradiation n0 in the present invention.

An actual number of times of irradiation n is set at (n0-1) or greater and 3·n0 or less with respect to the number of times of irradiation n0. By this means, it is possible to effectively and efficiently crystalize the non-single crystalline semiconductor film 2.

[0028]

In the crystalline semiconductor film crystalized by irradiation with the above-described pulse laser, thin film semiconductors are formed at predetermined intervals. The interval is preferably set at 1 mm or less. Further, each of the thin film semiconductors has a predetermined

channel length b, which is designed to be 100 μm or less, and, preferably, 6 to 40 μm.

A state where thin film semiconductors 10 are arranged on the non-single crystalline semiconductor film 2 is illustrated in Figure 5. Each thin film semiconductor 10 has a source 11, a drain 12, and a channel portion 13 positioned between the source and the drain, and a scanning direction of the pulse laser of the channel portion 13 is the channel length b. If the pulse laser 3 is radiated on the non-single crystalline semiconductor film 2 and moved at a scanning pitch (the amount of movement for each pulse) c, a beam joint 3a appears on the crystalline semiconductor film according to movement for each pulse.

[0029]

Figure 5(a) illustrates a state where the beam joints 3a occur when the amount of movement c for each pulse is made greater than the channel length b. In this example, the beam joint 3a is not positioned (0) or one beam joint 3a appears in the channel portion 13, which results in large variation in performance of the thin film semiconductor 10.

Figure 5(b) illustrates a state where the beam joints 3a occur when the amount of movement c for each pulse is set at 1/2 of the channel length b or greater and less than the channel length b. In this example, one or two beam joints 3a appear in the channel portion 13,

and variation in performance of the thin film semiconductor 10 is drastically reduced compared to a case in Figure 5(a).

Figure 5(c) illustrates a state where the beam joints 3a occur when the amount of movement c for each pulse is set at less than 1/2 of the channel region width b. In this example, n or (n+1) or more (where n is an integer of two or greater) beam joints 3a appear, which significantly reduces variation in performance of the thin film semiconductor 10.

Example 1

[0030]

An example of the present invention will be described below.

A pulse laser was radiated under the following conditions while using amorphous Si having a thickness of 50 nm as a non-single crystalline semiconductor film and while changing the number of times of irradiation.

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

Beam size: beam length 500 mm × beam width 0.16 mm, a beam width is a high intensity region where energy intensity is 96% or higher of maximum energy intensity.

Flat portion within the region

Scanning pitch: 40 μm to 8 μm

Irradiation pulse energy density: 370 mJ/cm^2

Channel length: 20 μm

[0031]

In the above-described pulse laser, while it could be acknowledged that the irradiation pulse energy density was equal to or less than irradiation pulse energy density at which fine crystallization occurred, and the crystal grain size gradually grew while the number of times of irradiation increased from four to eight, the crystal grain size growth was saturated when the number of times of irradiation was eight or greater.

[0032]

A portion irradiated with the pulse laser a predetermined number of times of irradiation was observed through SEM photographs, which are illustrated in Figure 6. As illustrated in Figure 6, crystallization preferably occurred when the number of times of irradiation was eight, and the crystal grain size did not substantially increase even if the number of times of irradiation was increased to 12, 16 and 20.

Figure 7 illustrates change of the crystal grain size according to the number of times of irradiation, and the crystal grain size increases in accordance with increase of the number of times of irradiation until the number of times of irradiation reached eight. The crystal grain size did not increase when the number of times of irradiation was eight or greater.

Accordingly, an arbitrary number of times of irradiation equal to or greater than eight, that is, the amount of movement between pulses, can be determined, and the amount of movement becomes less than the channel length when the number of times of irradiation is nine, and the amount of movement becomes less than 1/2 of the channel length when the number of times of irradiation is 17.

Reference Signs List

[0033]

1 Moving stage

2 Non-single crystalline semiconductor film

3 Pulse laser

3a Beam joint

10 Thin film semiconductor

11 Source

12 Drain

13 Channel portion

Claims

[Claim 1]

A manufacturing method of a crystalline semiconductor film in which scanning is relatively performed on a non-single crystalline semiconductor film with a pulse laser shaped into a line beam shape having a flat portion in a shape of a beam cross-section in a beam short axis direction, the pulse laser having a beam short axis width of 100 to 500 μm, so that the pulse laser is made to move for each pulse, and the non-single crystalline semiconductor film is irradiated by the pulse laser with a number of times of irradiation (n) in an overlapped manner, wherein

a channel length of a transistor formed on the semiconductor film is (b) (100 μm or less),

the pulse laser has irradiation pulse energy density (E) lower than irradiation pulse energy density at which fine crystallization occurs at the non-single crystalline semiconductor film by irradiation with the pulse laser and at which crystal grain size growth is saturated by a plurality of times of irradiation,

the number of times of irradiation (n) with the pulse laser is set at (n0-1) or greater when the number of times of irradiation at which the crystal grain size growth is saturated by irradiation with the pulse laser having the irradiation pulse energy density E is n0, and

a scanning direction of the pulse laser is a channel length direction of the transistor, and an amount of movement (c) for each of the pulses is set at less than (b).

[Claim 2]

The manufacturing method of the crystalline semiconductor film according to claim 1, wherein the number of times of irradiation (n) with the pulse laser is (n0-1) or greater and (3·n0) or less.

[Claim 3]

The manufacturing method of the crystalline semiconductor film according to claim 1 or 2, wherein the amount of movement is less than (b/2).

[Claim 4]

The manufacturing method of the crystalline semiconductor film according to any of claims 1 to 3, wherein the amount of movement is 5 μm or greater.

[Claim 5]

The manufacturing method of the crystalline semiconductor film according to any of claims 1 to 4, wherein a ratio of a channel width and a channel length (channel width/channel length) of the transistor is 1 or less.

[Claim 6]

The manufacturing method of the crystalline semiconductor film according to any of claims 1 to 5, wherein the non-single crystalline semiconductor is Si.

[Claim 7]

The manufacturing method of the crystalline semiconductor film according to any of claims 1 to 6, wherein the pulse laser is an excimer laser.