energy density with which microcrystallization occurs to the non-single-crystal semiconductor film by irradiation of the pulse laser, and is suitable for crystallization by irradiation of a plurality of times N being set as E0,

a first step of irradiating a plurality of times N1 with the pulse laser having an irradiation pulse energy density E1 which is the same as the irradiation pulse energy density E0; and

a second step of irradiating after the first step, a plurality of times N2 with the pulse laser having an irradiation pulse energy E2 which is lower than the irradiation pulse energy density E1, and is equal to or higher than an irradiation energy density that is necessary for a crystal to be remelted,

wherein the total number of times of irradiation to the same irradiation surface in the first step and the second step (N1 + N2) is equal to or larger than N times.

According to the second aspect of the present invention, a manufacturing apparatus of a crystal semiconductor is provided. The manufacturing apparatus comprises

one or two or more laser light sources that outputs or output a pulse laser;

an optical system that shapes the pulse laser and guides the pulse laser to a non-single-crystal semiconductor;

an energy regulating section that regulates an irradiation energy density of the pulse laser;

scanning device with the irradiation pulse energy density E2, to the semiconductor irradiated N1 times with the pulse laser in the first step.

According to a third aspect of the present invention, a manufacturing apparatus of a crystal semiconductor film is provided. The manufacturing apparatus comprises

one or two or more laser light sources that outputs or output a pulse laser;

an optical system that shapes the pulse laser and guides the pulse laser to a non-single-crystal semiconductor;

an intensity regulating section that regulates, in a beam section intensity distribution in a scan direction of the pulse laser, the intensity distribution so that intensity at a rear side in the scan direction to a rear end in the scan direction becomes lower than intensity at a front side in the scan direction, and an irradiation pulse energy density by the intensity at the rear side in the scan direction becomes 0.95 times or more an irradiation pulse energy density by the intensity at the front side in the scan direction;

an energy regulating section that regulates an irradiation energy density of the pulse laser;

a scanning device that causes the pulse laser to scan relatively to the non-single-crystal semiconductor; and

Claims

[Claim 1]

A manufacturing method of a crystal semiconductor film that performs crystallization by applying overlap irradiation while causing a pulse laser to scan relatively in a short axis direction, onto a non-single-crystal semiconductor film, comprising:

with an irradiation pulse energy density which is lower than an irradiation pulse energy density with which microcrystallization occurs to the non-single-crystal semiconductor film by irradiation of the pulse laser, and is suitable for crystallization by irradiation of a plurality of times N being set as E0,

a first step of irradiating a plurality of times N1 with the pulse laser having an irradiation pulse energy density E1 which is the same as the irradiation pulse energy density E0; and

a second step of irradiating ,after the first step, a plurality of times N2 with the pulse laser having an irradiation pulse energy E2 which is lower than the irradiation pulse energy density E1, and is equal to or higher than an irradiation energy density that is necessary for a crystal to be remelted,

wherein the total number of times of irradiation to the same irradiation surface in the first step and the second step (N1+N2) is equal to or larger than N times.

[Claim 2]

The manufacturing method of a crystal semiconductor film according to claim 1,

wherein the irradiation pulse energy suitable for crystallization is within a range of E × 0.98 to E × 1.03 where an irradiation pulse energy density with which crystal grain size growth is saturated by irradiation of the plurality of times N is E.

[Claim 3]

The manufacturing method of a crystal semiconductor film according to claim 1 or 2,

wherein the irradiation pulse energy density E2 is equal to or higher than E1 × 0.95.

[Claim 4]

The manufacturing method of a crystal semiconductor film according to any of claims 1 to 3,

wherein the total number of times of irradiation is equal to or smaller than N × 1.5.

~~[Claim 5]~~

~~The manufacturing method of a crystal semiconductor film according to any of claims 1 to 4,~~

~~wherein irradiation of a plurality of times N1 to the same irradiation surface is sequentially performed while the pulse laser is caused to scan by the first step, thereafter, to the predetermined surface, irradiation of~~

~~a plurality of times N2 to the same irradiation surface is sequentially performed while the pulse laser is caused to scan by the second step, and the N1 + N2 is set as the total number of irradiation times and is made equal to or larger than N times.~~

[Claim 5 ~~6~~]

The manufacturing method of a crystal semiconductor film according to any of claim 1 to 4 ~~5~~,

wherein the N1 is made the number of times which is equal to or larger than the N2.

~~[Claim 7]~~

~~The manufacturing method of a crystal semiconductor film according to any one of claims 1 to 6,~~

~~wherein in a beam section intensity distribution in a scan direction, the pulse laser has lower intensity at a rear side in the scan direction to a rear end in the scan direction than intensity at a front side in the scan direction, and irradiation of the first step is performed in accordance with the intensity at the front side in the scan direction, whereas irradiation of the second step is performed in accordance with the intensity at the rear side in the scan direction.~~

~~[Claim 8]~~

~~The manufacturing method of a crystal semiconductor film according to claim 7,~~

~~wherein a width in the scan direction at the front side in the scan direction is equal to or larger than a width in the scan direction at the rear side in the scan direction.~~

[Claim 6 ~~9~~]

The manufacturing method of a crystal semiconductor film according to any of claims 1 to 5 ~~8~~,

wherein a wavelength of the pulse laser is equal to or shorter than 400 nm.

[Claim 7 ~~10~~]

The manufacturing method of a crystal semiconductor film according to any of claims 1 to 6 ~~9~~,

wherein a full width at half maximum of the pulse laser is equal to or smaller than 200 ns.

[Claim 8 ~~11~~]

The manufacturing method of a crystal semiconductor film according to any of claims 1 to 7 ~~10~~,

wherein the non-single-crystal semiconductor is of silicon.

[Claim 9 ~~12~~]

scanning device with the irradiation pulse energy density E1, and a second step of controlling the energy regulating section to regulate the irradiation pulse energy density to irradiation pulse energy E2 which is lower than the irradiation pulse energy density E1, and is equal to or higher than an irradiation energy density necessary for a crystal to be remelted, and sequentially performing irradiation of a plurality of times N2 ($N2 < N$, $N1 + N2 \geq N$) to the non-single-crystal semiconductor while causing the pulse laser to scan by controlling the scanning device with the irradiation pulse energy density E2, to the semiconductor irradiated N1 times with the pulse laser in the first step.

~~[Claim 13]~~

~~A manufacturing apparatus of a crystal semiconductor film, comprising:~~

~~one or two or more laser light sources that outputs or output a pulse laser;~~

~~an optical system that shapes the pulse laser and guides the pulse laser to a non-single-crystal semiconductor;~~

~~an intensity regulating section that regulates, in a beam section intensity distribution in a scan direction of the pulse laser, the intensity distribution so that intensity at a rear side in the scan direction to a rear end in the scan direction becomes lower than intensity at~~

~~a front side in the scan direction, and an irradiation pulse energy density by the intensity at the rear side in the scan direction becomes 0.95 times or more an irradiation pulse energy density by the intensity at the front side in the scan direction;~~

~~an energy regulating section that regulates an irradiation energy density of the pulse laser;~~

~~a scanning device that causes the pulse laser to scan relatively to the non-single-crystal semiconductor; and~~

~~a control section that controls the laser light source, the energy regulating section and the scanning device,~~

~~wherein the control section executes a step of controlling the energy regulating section to perform regulation so that in irradiation at the front side in the scan direction of the pulse laser, an irradiation pulse energy density becomes an irradiation pulse energy density E1 which is lower than an irradiation pulse energy density with which microcrystallization occurs to the non-single-crystal semiconductor film, and is the same as an irradiation pulse energy density E0 which is suitable for crystallization by irradiation of a plurality of times N, and in irradiation at the rear side in the scan direction of the pulse laser, an irradiation pulse energy density becomes an irradiation pulse energy E2 which is lower than the irradiation pulse energy~~

~~density E1, and is equal to or higher than an irradiation energy density which is necessary for a crystal to be remelted, and sequentially performing irradiation of a plurality of times which is equal to or larger than N times to the non-single-crystal-semiconductor while causing the pulse laser to scan by controlling the scanning device.~~

[Claim 10 ~~14~~]

The manufacturing apparatus of a crystal semiconductor film according to claim 9 ~~12 or 13~~,

wherein the control section sets the irradiation pulse energy suitable for crystallization to be within a range of E × 0.98 to E × 1.03 where an irradiation pulse energy density with which crystal grain size growth is saturated by irradiation of the plurality of times N is E.