the intervals, and are recognized as irradiation unevenness.

Accordingly, if the pulse laser is applied by making the irradiation energy density low, the above described irradiation unevenness can be reduced, but for this purpose, it is necessary to apply a laser on the same irradiation surface a larger number of irradiation times, and the production efficiency is declined. Further, if the irradiation pulse energy density becomes too low, there arises a problem that the crystal grain size does not become sufficiently large.

[0009] ~~The~~ Embodiments of the present invention ~~is~~ are made against the backdrop of the above described circumstances, and ~~one of objects~~embodiments of the invention ~~is~~ are to provide a manufacturing method and a manufacturing apparatus of a crystal semiconductor film that can eliminate irradiation unevenness on a semiconductor film by an edge portion in a scan direction of a pulse laser in addition to restraining reduction in productivity as much as possible.

According to a first aspect of the present invention, 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 is provided.

The method comprises 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 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 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 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;

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 first step of controlling the energy regulating section to regulate the irradiation pulse energy density to 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 by irradiation of the pulse laser, 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 sequentially performing irradiation of a plurality of times N1 ($N1 < N$) to the non-single crystal semiconductor while causing the pulse laser to scan by controlling the scanning device with the irradiation pulse energy density 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 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

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.

Solution to Problem

[0010] That is to say, in a manufacturing method of a crystal semiconductor film of the present invention, a

first present invention is a manufacturing method of a crystal semiconductor film that performs crystallization by applying overlap irradiation while causing pulse.