1. A laser annealing apparatus comprising:

a pulsed laser oscillator to output a pulsed laser beam, and

an optical transmission means to transmit the pulsed laser beam output from the pulsed laser oscillator to irradiate a semiconductor film with the pulsed laser beam, wherein

the pulsed laser beam is irradiated on the semiconductor film in a condition where an effective power density of the pulsed laser beam calculated by the following formula falls within a range of from 3×10^{12} to 1.5×10^{12} on an irradiation surface of the semiconductor film.

effective power density ($J/(sec \cdot cm^3)$) = pulse energy density (J/cm^2) / pulse width (sec) × absorption coefficient of semiconductor film (cm^{-1}) ••• (Formula)

2. A laser annealing apparatus comprising:

a continuous laser oscillator to output a continuous laser beam;

an optical transmission mean to transmit the continuous laser beam output from the continuous laser oscillator and a pulsed laser beam split from the continuous laser beam to irradiate a semiconductor film with the pulsed laser beam; and

pulsed laser beam generating means to split the continuous laser beam during the transmission into a pseudo pulsed shape to thereby generate the pulsed laser beam; wherein

the pulsed laser beam is irradiated on the semiconductor film in a condition where an effective power density of the pulsed laser beam calculated by the following formula falls

within a range of from 3×10^{12} to 1.5×10^{12} on an irradiation surface of the semiconductor film.

effective power density ($J/(sec \cdot cm^3)$) = pulse energy density (J/cm^2) / pulse width (sec) × absorption coefficient of semiconductor film (cm^{-1}) ••• (Formula)

3. The laser annealing apparatus according to Claim 1 or 2, further comprising:

an energy adjusting means to adjust an energy density of the pulsed laser beam, wherein the energy density is defined in the energy adjusting means in such a manner that the effective power density calculated by the formula falls within the range of from 3×10^{12} to 1.5×10^{12}.

4. The laser annealing apparatus according to Claim 3, comprising, as the energy adjusting means, an attenuator to transmit the pulsed laser beam attenuated at a predetermined attenuation rate and an output adjusting means to adjust an output of the laser oscillator, wherein the attenuation rate and the output are defined in the attenuator and the output adjusting means in such a manner that the effective power density calculated by the formula falls within the range of from 3×10^{12} to 1.5×10^{12}.

5. The laser annealing apparatus according to any one of Claims 1 to 4, further comprising a pulse width adjusting means to adjust a pulse width of the pulsed laser beam, wherein the pulse width adjusting means adjusts the pulse width in such a manner that the effective power density calculated by the formula falls within the range of from 3×10^{12} to 1.5×10^{12}.

6. The laser annealing apparatus according to any one of Claims 1 to 5, wherein the semiconductor film is a silicon semiconductor film, the energy density is from 100 to 500 mJ/cm^2, and the pulse width is from 50 to 500 nsec.

7. A laser annealing method for irradiating a semiconductor film with a pulsed laser beam to perform laser annealing of the semiconductor film, the method comprising:

defining a pulse energy density and a pulse width of the pulsed laser beam in such a manner that the pulsed laser beam has an effective power density calculated by the following formula falls within a range of from 3×10^{12} to 1.5×10^{12} on an irradiated surface, and irradiating the semiconductor film with the pulsed laser beam having the defined pulse energy density and pulse width.

effective power density ($J/(sec \cdot cm^3)$) = pulse energy density (J/cm^2) / pulse width (sec) × absorption coefficient of semiconductor film (cm^{-1}) ••• (Formula)

CLAIMS

1. A laser annealing apparatus which irradiates an amorphous semiconductor film with a pulsed laser beam in a state of heating where the amorphous semiconductor film is not completely molten to perform crystallization of the amorphous semiconductor film comprising:

a pulsed laser oscillator to output a pulsed laser beam, and

an optical transmission means to transmit the pulsed laser beam output from the pulsed laser oscillator to irradiate a semiconductor film with the pulsed laser beam, wherein

the pulsed laser beam is irradiated on the semiconductor film in a condition where the pulsed laser beam has an energy density of from 100 to 400 mJ/cm^2 and an effective power density calculated by the following formula within a range of from 2.7×10^{12} to 1.5×10^{12} on an irradiation surface of the semiconductor film.

effective power density $(J/(sec \cdot cm^3))$ = pulse energy density (J/cm^2) / pulse width (sec) × absorption coefficient of semiconductor film (cm^{-1}) ••• (Formula)

2. A laser annealing apparatus which irradiates an amorphous semiconductor film with a pulsed laser beam in a state of heating where the amorphous semiconductor film is not completely molten to carry out crystallization of the amorphous semiconductor film comprising:

a continuous laser oscillator to output a continuous laser beam;

an optical transmission mean to transmit the continuous laser beam output from the continuous laser oscillator and a pulsed laser beam split from the continuous laser beam to

irradiate a semiconductor film with the pulsed laser beam; and

pulsed laser beam generating means to split the continuous laser beam during the transmission into a pseudo pulsed shape to thereby generate the pulsed laser beam; wherein

the pulsed laser beam is irradiated on the semiconductor film in a condition where an effective power density of the pulsed laser beam calculated by the following formula within a range of from 2.7×10^{12} to 1.5×10^{12} on an irradiation surface of the semiconductor film.

effective power density ($J/(sec \cdot cm^3)$) = pulse energy density (J/cm^2) / pulse width (sec) × absorption coefficient of semiconductor film (cm^{-1}) ••• (Formula)

3. The laser annealing apparatus according to Claim 1 or 2, further comprising:

an energy adjusting means to adjust an energy density of the pulsed laser beam, wherein the energy density is defined in the energy adjusting means in such a manner that the effective power density calculated by the formula falls within the range of from 2.7×10^{12} to 1.5×10^{12}.

4. The laser annealing apparatus according to Claim 3, comprising, as the energy adjusting means, an attenuator to transmit the pulsed laser beam attenuated at a predetermined attenuation rate and an output adjusting means to adjust an output of the laser oscillator, wherein the attenuation rate and the output are defined in the attenuator and the output adjusting means in such a manner that the effective power density calculated by the formula falls within the range of from ~~3~~2.7 × 10^{12} to 1.5×10^{12}.

5. The laser annealing apparatus according to any one of Claims 1 to 4, further comprising a pulse width adjusting means to adjust a pulse width of the pulsed laser beam, wherein the pulse width adjusting means adjusts the pulse width in such a manner that the effective power density calculated by the formula falls within the range of from 2.7×10^{12} to 1.5×10^{12}.

6. The laser annealing apparatus according to any one of Claims 1 to 5, wherein the semiconductor film is a silicon semiconductor film, and the pulse width is from 50 to 500 nsec.

7. A laser annealing method for irradiating an amorphous semiconductor film with a pulsed laser beam in a state of heating where the amorphous semiconductor film is not completely molten to perform crystallization of the semiconductor film, the method comprising:

defining a pulse energy density and a pulse width of the pulsed laser beam in such a manner that the pulsed laser beam has an energy density of from 100 to 400 mJ/cm^2 and an effective power density calculated by the following formula within a range of from 2.7×10^{12} to 1.5×10^{12} on an irradiated surface, and irradiating the semiconductor film with the pulsed laser beam having the defined pulse energy density and pulse width.

effective power density $(J/(sec \cdot cm^3))$ = pulse energy density (J/cm^2) / pulse width (sec) × absorption coefficient of semiconductor film (cm^{-1}) ••• (Formula)