CLAIMS

1. An inspection method of a substrate with a crystallized film, the method comprising the steps of:

(A) irradiating an amorphous film over a substrate with a laser beam to crystallize the amorphous film and to form a crystallized film;

(B) irradiating the crystallized film with a probe beam;

(C) detecting, by a photodetector, the probe beam transmitted through the crystallized film;

(D) changing an irradiation position of the probe beam onto the crystallized film to acquire a plurality of detection values of a detection signal from the photodetector; and

(E) determining, based on a standard deviation of the plurality of detection values, a crystalline state of the crystallized film, wherein

the laser beam forms a linear irradiation region on the amorphous film by a projection lens, and

the photodetector detects the probe beam having passed through the projection lens.

2. The inspection method according to Claim 1, wherein the step (E) comprises:

comparing the standard deviation with a threshold; and

determining the substrate to be non-defective when the standard deviation is less than the threshold or determining the substrate to be defective when the standard deviation is equal to or greater than the threshold.

3. The inspection method according to Claim 1 or 2, wherein the step (E) further comprises determining the crystalline state based on an average value of the plurality of detection values.

4. The inspection method according to any one of Claims 1 to 3, wherein

the probe beam forms a linear illumination region on the crystallized film, and

the probe beam transmitted through the crystallized film is condensed on the photodetector by a condenser lens.

5. The inspection method according to any one of Claims 1 to 4, wherein the step (D) comprises conveying the substrate to change an irradiation position of the laser beam and the irradiation position of the probe beam while the substrate is being irradiated simultaneously with the laser beam and the probe beam.

6. The inspection method according to any one of Claims 1 to 3, wherein

the step (A) comprises irradiating the amorphous film with the laser beam while the substrate placed over a stage is being moved,

the step (B) comprises irradiating the amorphous film with the probe beam outside the stage, and

the step (D) comprises carrying the substrate on the stage out by a robot hand to change the irradiation position of the probe beam.

7. The inspection method according to Claim 6, wherein the step (C) comprises detecting, by the photodetector, the probe beam having passed through the crystallized film twice or more.

8. A manufacturing method of a semiconductor device, the method comprising the steps of:

(a) forming an amorphous film over a substrate;

(b) irradiating the amorphous film with a laser beam to crystallize the amorphous film and to form a crystallized film;

(c) irradiating the crystallized film with a probe beam;

(d) detecting, by a photodetector, the probe beam transmitted through the crystallized film;

(e) changing an irradiation position of the probe beam onto the crystallized film to acquire a plurality of detection values of a detection signal output from the photodetector;

(f) determining, based on a standard deviation of the plurality of detection values, a crystalline state of the crystallized film; and

(g) re-irradiating the crystallized film with the laser beam according to a determination result of the crystalline state, wherein

the laser beam forms a linear irradiation region on the amorphous film by a projection lens, and

the photodetector detects the probe beam having passed through the projection lens.

9. The manufacturing method according to Claim 8, wherein the step (f) comprises:

comparing the standard deviation with a threshold; and

determining the substrate to be non-defective when the standard deviation is less than the threshold or determining the substrate to be defective when the standard deviation is equal to or greater than the threshold.

10. The manufacturing method according to Claim 8 or 9, wherein the step (f) further comprises determining the crystalline state based on an average value of the plurality of detection values.

11. The manufacturing method according to any one of Claims 8 to 10, wherein

the probe beam forms a linear illumination region on the crystallized film, and

the probe beam transmitted through the crystallized film is condensed on the photodetector by a condenser lens.

12. The manufacturing method according to any one of Claims 8 to 11, wherein the step (e) comprises changing an irradiation position of the laser beam and the irradiation position of the probe beam while the substrate is being irradiated simultaneously with the laser beam and the probe beam.

13. The manufacturing method according to any one of Claims 8 to 10, wherein

the step (b) comprises irradiating the amorphous film with the laser beam while the substrate placed over a stage is being moved,

the step (c) comprises irradiating the amorphous film with the probe beam outside the stage, and

the step (e) comprises carrying the substrate on the stage out by a robot hand to change the irradiation position of the probe beam.

14. The manufacturing method according to Claim 13, wherein the step (d) comprises detecting, by the photodetector, the probe beam having passed through the crystallized film twice or more.

15. A laser annealing apparatus comprising:

a laser beam source configured to emit a laser beam to crystallize an amorphous film over a substrate and to form a crystallized film;

a projection lens configured to condense the laser beam to irradiate the amorphous film, wherein the projection lens is configured to cause the laser beam to form a linear irradiation region on the amorphous film;

a probe beam source configured to emit a probe beam;

a photodetector configured to detect the probe beam transmitted through the crystallized film, wherein the photodetector is configured to detect the probe beam having passed through the projection lens;

a conveying path configured to convey the substrate to change an irradiation position of the laser beam onto the substrate; and

a processing unit configured to change an irradiation position of the probe beam onto the substrate, to calculate a standard deviation of detection values of a detection signal output from the photodetector, and to determine a crystalline state of the crystallized film based on the standard deviation.

16. The laser annealing apparatus according to Claim 15, wherein the processing unit is configured to:

compare the standard deviation with a threshold; and

determine the substrate to be non-defective when the standard deviation is less than the threshold or determine the substrate to be defective when the standard deviation is equal to or greater than the threshold.

17. The laser annealing apparatus according to Claim 15 or 16, wherein the processing unit configured to determine the crystalline state based on an average value of the detection values.

18. The laser annealing apparatus according to any one of Claims 15 to 17, further comprising:

a cylindrical lens configured to cause the probe beam to form a linear illumination region on the crystallized film; and

a condenser lens configured to condense the probe beam transmitted through the crystallized film on the photodetector.

19. The laser annealing apparatus according to any one of Claims 15 to 18, wherein the conveying path is configured to convey the substrate while the substrate is being irradiated simultaneously with the laser beam and the probe beam.

20. The laser annealing apparatus according to any one of Claims 15 to 19, wherein the conveying path comprises a gas-floating

unit configured to jet gas to the substrate to float the substrate.

21. The laser annealing apparatus according to any one of Claims 15 to 17, further comprising a stage configured to hold the substrate, wherein

the stage is configured to be moved to convey the substrate along the conveying path,

the laser annealing apparatus comprises a carrying-out port which a conveying robot that carries the substrate out from the stage enters, and

the irradiation position of the probe beam onto the substrate is changed by the conveying robot carrying the substrate out from the stage.

22. The laser annealing apparatus according to Claim 21, wherein the photodetector is configured to detect the probe beam having passed through the crystallized film twice or more.

23. A laser annealing apparatus comprising:

a laser beam source configured to emit a laser beam to crystallize an amorphous film over a substrate and to form a crystallized film;

a projection lens configured to condense the laser beam to irradiate the amorphous film, wherein the projection lens is configured to cause the laser beam to form a linear irradiation region on the amorphous film;

a stage configured to convey the substrate to change an irradiation position of the laser beam onto the substrate;

a probe beam source configured to emit a probe beam;

a photodetector configured to detect the probe beam transmitted through the crystallized film outside the stage during a conveying robot takes out the substrate from the stage, wherein the photodetector is configured to detect the probe beam having passed through the projection lens; and

a processing unit configured to determine a crystalline state of the crystallized film based on a detection signal output from the photodetector.