CLAIMS

1. A substrate heat treatment apparatus comprising:

a placement unit on which a substrate is placed;

a heat treatment unit for heating or cooling the substrate on the placement unit;

a plurality of temperature sensors positioned correspondingly to a plurality of locations of the substrate on the placement unit; and

a control unit configured to control the heat treatment unit based on temperatures detected by the temperature sensors, configured to calculate a position of a thermal center of gravity of the substrate based on the temperatures detected by the temperature sensors, and configured to detect heat treatment condition of the substrate based on the position of the thermal center of gravity, the thermal center of gravity corresponding to a center of gravity on the assumption that the temperatures detected by the temperature sensors are regarded as weights,

wherein the control unit is configured to calculate, as a first position of a thermal center of gravity, the position of the thermal center of gravity in a plane of the substrate, configured to calculate, as a second position of a thermal center of gravity, the position of the thermal center of gravity in a radial direction perpendicular to the center of the substrate, and configured to detect the heat treatment condition of the substrate based on the first and second positons of the thermal center of gravity.

2. The substrate heat treatment apparatus according to claim 1, wherein the control unit is configured to calculate the position of the second thermal center of gravity, by regarding an average value of the temperatures detected by the temperature sensors whose positions with respect to the radial direction are identical to each other, as a weight of the position.

3. The substrate heat treatment apparatus according to claim 1, wherein the control unit is configured to calculate the second position of center of gravity, by regarding an average value of the temperatures detected by the temperature sensors in each of annular areas, which are concentric with the substrate and arranged in different radial positions, as a weight of the area.

4. The substrate heat treatment apparatus according to any one of claim 1 to 3, wherein the control unit is configured to use a reference position that is determined based on the position of the thermal center of gravity when the substrate is normally heat-treated, and configured to detect the heat treatment condition of the substrate based on a difference between the position of the thermal center of gravity and the reference position.

5. A substrate heat treatment apparatus comprising:

a placement unit on which a substrate is placed;

a heat treatment unit for heating or cooling the substrate on the placement unit;

a plurality of temperature sensors positioned correspondingly to a plurality of locations of the substrate on the placement unit; and

a control unit configured to control the heat treatment unit based on temperatures detected by the temperature sensors, configured to calculate a position of a thermal center of gravity of the substrate based on the temperatures detected by the temperature sensors, and configured to detect heat treatment condition of the substrate based on the position of the thermal center of gravity, the thermal center of gravity corresponding to a center of gravity on the assumption that the temperatures detected by the temperature sensors are regarded as weights,

wherein the control unit is configured to use a reference position that is determined based on the position of the thermal center of gravity when the substrate is normally heat-treated, and configured to detect the heat treatment condition of the substrate based on a difference between the position of the thermal center of gravity and the reference position, and wherein the control unit is configured to use, as the reference position, an average value of the positions of the thermal center of gravity, which is calculated in normal heat treatments of plural times, to further use an allowable range determined based on a standard deviation of the positions of the thermal center of gravity, which is calculated in normal heat treatments of plural times, and to detect that the heat treatment condition of the substrate is abnormal when a difference between the position of the thermal center of gravity and the reference position is out of the allowable range.

6. The substrate heat treatment apparatus according to any one of claims 1 to 5, wherein the control unit is configured to further output information related to the position of the thermal center of gravity.

7. A substrate heat treatment apparatus comprising:

a placement unit on which a substrate is placed;

a heat treatment unit for heating or cooling the substrate on the placement unit;

a plurality of temperature sensors positioned correspondingly to a plurality of locations of the substrate on the placement unit; and

a control unit configured to control the heat treatment unit based on temperatures detected by the temperature sensors, configured to calculate a position of a thermal center of gravity of the substrate based on the temperatures detected by the temperature sensors, and configured to detect heat treatment condition of the substrate based on the position of the thermal center of gravity,

the thermal center of gravity corresponding to a center of gravity on the assumption that the temperatures detected by the temperature sensors are regarded as weights,

wherein the control unit is configured to use a reference position that is determined based on the position of the thermal center of gravity when the substrate is normally heat-treated, and configured to detect the heat treatment condition of the substrate based on a difference between the position of the thermal center of gravity and the reference position, and wherein the control unit is configured to further output information related to the position of the thermal center of gravity.

8. The substrate heat treatment apparatus according to any one of claims 1 to 7, wherein

the heat treatment unit is capable of independently controlling the heat treatment condition of a plurality of treatment areas arranged in a plane of the substrate, and

the control unit is configured to further identify a treatment area in which the heat treatment is insufficient based on the position of the thermal center of gravity, and configured to promote the heat treatment in the treatment area.

9. The substrate heat treatment apparatus according to any one of claims 1 to 8, wherein

the control unit is configured to calculate the position of the thermal center of gravity by the following expression (1) and (2):

$$X = \frac{\sum_{i=1}^{n} xi \cdot Ti}{\sum_{i=1}^{n} Ti} \cdots (1)$$

$$Y = \frac{\sum_{i=1}^{n} yi \cdot Ti}{\sum_{i=1}^{n} Ti} \cdots (2)$$

where:

"X" and "Y" are coordinate values indicating the position of the thermal center of gravity in orthogonal coordinate system;

"xi" and "yi" are coordinate values indicating the position of the temperature sensor in the orthogonal coordinate system;

"Ti" is the temperature detected by each temperature sensors; and

"n" is the number of the temperature sensors.

10. A substrate heat treatment method comprising:

placing a substrate on a placement unit;

heating or cooling the substrate on the placement unit by a heat treatment unit;

detecting temperatures by a plurality of temperature sensors positioned correspondingly to a plurality of locations of the substrate on the placement unit;

controlling the heat treatment unit based on the temperatures detected by the temperature sensors;

calculating a position of a thermal center of gravity based on the temperatures detected by the temperature sensors, the thermal center of gravity corresponding a center of gravity on the assumption that the temperatures detected by the temperature sensors are regarded as weights; and

detecting heat treatment condition of the substrate based on the position of the thermal center of gravity;

wherein, the position of the thermal center of gravity in a plane of the substrate is calculated as a first position of a thermal center of gravity, the position of the thermal center of gravity in a radial position of the substrate perpendicular to the center of the substrate is calculated as a second position of

a thermal center of gravity, and the heat treatment condition of the substrate is detected based on the first and second positions of the center of gravity.

11. The substrate heat treatment method according to claim 10, wherein the position of the second thermal center of gravity is calculated by regarding an average value of the temperatures detected by the temperature sensors whose positions with respect to the radial direction are identical to each other, as a weight of the position.

12. The substrate heat treatment method according to claim 10, wherein the position of the second thermal center of gravity is calculated by regarding an average value of the temperatures detected by the temperature sensors in each of annular areas, which are concentric with the substrate and arranged in different radial positions, as a weight of the area.

13. The substrate heat treatment method according to any one of claims 10 to 12, wherein a reference position is used, which is determined based on the position of the thermal center of gravity when the substrate is normally heat-treated, and the heat treatment condition of the substrate is detected based on a difference between the position of the thermal center of gravity and the reference position.

14. A substrate heat treatment method comprising:

placing a substrate on a placement unit;

heating or cooling the substrate on the placement unit by a heat treatment unit;

detecting temperatures by a plurality of temperature sensors positioned correspondingly to a plurality of locations of the substrate on the placement unit;

controlling the heat treatment unit based on the temperatures detected by the temperature sensors;

calculating a position of a thermal center of gravity based on the temperatures detected by the temperature sensors, the thermal center of gravity corresponding a center of gravity on the assumption that the temperatures detected by the temperature sensors are regarded as weights; and

detecting heat treatment condition of the substrate based on the position of the thermal center of gravity;

wherein a reference position is used, which is determined based on the position of the thermal center of gravity when the substrate is normally heat-treated, and the heat treatment condition of the substrate is detected based on a difference between the position of the thermal center of gravity and the reference position, and

wherein an average value of the positions of the thermal center of gravity, which is calculated in normal heat treatments of plural times, is used as the reference position, an allowable range determined based on a standard deviation of the positions of the thermal center of gravity, which is calculated in normal heat treatments of plural times, is further used, and when a difference between the position of the thermal enter of gravity and the reference position is out of the allowable range, the heat treatment condition of the substrate is detected as abnormal.

15. The substrate heat treatment method according to any one of claims 10 to 14, further including outputting information related to the position of the thermal center of gravity.

16. A substrate heat treatment method comprising:

placing a substrate on a placement unit;

heating or cooling the substrate on the placement unit by a heat treatment unit;

detecting temperatures by a plurality of temperature sensors positioned correspondingly to a plurality of locations of the substrate on the placement unit;

controlling the heat treatment unit based on the temperatures detected by the temperature sensors;

calculating a position of a thermal center of gravity based on the temperatures detected by the temperature sensors, the thermal center of gravity corresponding a center of gravity on the assumption that the temperatures detected by the temperature sensors are regarded as weights; and

detecting heat treatment condition of the substrate based on the position of the thermal center of gravity;

wherein the substrate heat treatment method further includes:

using a reference position, which is determined based on the position of the thermal center of gravity when the substrate is normally heat-treated, and detecting the heat treatment condition of the substrate based on a difference between the position of the thermal center of gravity and the reference position; and

outputting trajectory information of the difference between the position of the thermal center of gravity and the reference position

17. The substrate heat treatment method according to any one of claims 10 to 16 further including identifying a treatment area in which the heat treatment is insufficient based on the position of the thermal center of gravity, and promoting the heat treatment in the treatment area.

18. The substrate heat treatment method according to any one of claims 10 to 17, wherein

the position of the thermal center of gravity is calculated by the following expressions (1) and (2):

$$X = \frac{\sum_{i=1}^{n} xi \cdot Ti}{\sum_{i=1}^{n} Ti} \cdots (1)$$

$$Y = \frac{\sum_{i=1}^{n} yi \cdot Ti}{\sum_{i=1}^{n} Ti} \cdots (2)$$

where:

"X" and "Y" are coordinate values indicating the position of the thermal center of gravity in orthogonal coordinate system;

"xi" and "yi" are coordinate values indicating the position of the temperature sensor in the orthogonal coordinate system;

"Ti" is the temperature detected by each temperature sensors; and

"n" is the number of the temperature sensors.

19. A computer-readable storage medium storing a program for causing an apparatus to execute the substrate heat treatment method according to any one of claims 10 to 18.

20. A heat-treatment-condition detecting apparatus configured to obtain temperatures detected by a plurality of temperature sensors positioned correspondingly to a plurality of locations of a substrate to be heat-treated on a placement unit, to calculate a position of a thermal center of gravity which corresponds to a center of gravity on the assumption that the temperatures are regarded as weights, and to detect heat treatment condition of the substrate based on the position of the thermal center of gravity,

wherein the heat-treatment-condition detecting apparatus is configured to calculate, as a first position of a thermal center of gravity, the position of the

thermal center of gravity in a plane of the substrate, configured to calculate, as a second position of a thermal center of gravity, the position of the thermal center of gravity in a radial direction perpendicular to the center of the substrate, and configured to detect the heat treatment condition of the substrate based on the first and second positons of the thermal center of gravity.

21. A heat-treatment-condition detecting apparatus configured to obtain temperatures detected by a plurality of temperature sensors positioned correspondingly to a plurality of locations of a substrate to be heat-treated on a placement unit, to calculate a position of a thermal center of gravity which corresponds to a center of gravity on the assumption that the temperatures are regarded as weights, and to detect heat treatment condition of the substrate based on the position of the thermal center of gravity,

wherein:

the heat-treatment-condition detecting apparatus is configured to use a reference position that is determined based on the position of the thermal center of gravity when the substrate is normally heat-treated, and configured to detect the heat treatment condition of the substrate based on a difference between the position of the thermal center of gravity and the reference position; and

the heat-treatment-condition detecting apparatus is configured to use, as the reference position, an average value of the positions of the thermal center of gravity, which is calculated in normal heat treatments of plural times, configured to use an allowable range determined based on a standard deviation of the positions of the thermal center of gravity, which is calculated in normal heat treatments of plural times, and configured to detect that the heat treatment condition of the substrate is abnormal when the difference between the position of the thermal center of gravity and the reference position is out of the allowable range.

22. A heat-treatment-condition detecting apparatus configured to obtain temperatures detected by a plurality of temperature sensors positioned correspondingly to a plurality of locations of a substrate to be heat-treated on a placement unit, to calculate a position of a thermal center of gravity which corresponds to a center of gravity on the assumption that the temperatures are regarded as weights, and to detect heat treatment condition of the substrate based on the position of the thermal center of gravity,

wherein:

the heat-treatment-condition detecting apparatus is configured to use a reference position that is determined based on the position of the thermal center of gravity when the substrate is normally heat-treated, and configured to detect the heat treatment condition of the substrate based on a difference between the position of the thermal center of gravity and the reference position; and

the heat-treatment-condition detecting apparatus is configured to further output trajectory information of the difference between the position of the thermal center of gravity and the reference position.