SPECIFICATION

Title of Invention: TEMPERATURE CONTROL METHOD FOR INSPECTION SYSTEM, AND INSPECTION SYSTEM

Technical Field

[0001]

The present disclosure relates to a temperature control method for an inspection system, and an inspection system.

Background

[0002]

Patent Document 1 discloses a control method for an inspection apparatus comprising a chuck on which a device under inspection is mounted, a tester that supplies power to the device under inspection to inspect the device under inspection, and a controller that controls the temperature of the chuck, wherein when feedback of an actual temperature of the device under inspection is not possible, a temperature difference between the temperature of the chuck and the temperature of the device under inspection is estimated based on a heat generation amount of the device under inspection, the target temperature of the chuck is corrected based on the target temperature of the device under inspection and the temperature difference, and the temperature of the chuck is controlled based on the corrected target temperature of the chuck and the actual temperature of the chuck.

Prior Art Documents

Patent Documents

[0003]

Patent Document 1: Japanese Laid-Open Patent Publication No. 2022-90538

Summary

Problems to Be Resolved by the Invention

[0004]

In one aspect, the present disclosure provides a temperature control method for an inspection system, and an inspection system, for inspecting a substrate while performing temperature control to suppress an overshoot of a junction temperature of an electronic device.

Means for Solving the Problems

[0005]

To solve the above-identified problem, according to one aspect, there can be provided a temperature control method for an inspection system comprising a chuck that holds a substrate having an electronic device to be inspected, and a tester that inspects the electronic device by applying an inspection power to the electronic device, the method comprising: modeling and obtaining a first transfer function of a temperature rise of the electronic device caused by heat generation resulting from applying the inspection power to the electronic device; modeling and obtaining a second transfer function of a temperature of the chuck when a set temperature of the chuck is changed; acquiring an inspection timing of the electronic device from the tester; and starting temperature control of the chuck

based on the first transfer function and the second transfer function before an inspection of the electronic device starts.

Effect of the Invention

[0006]

According to one aspect, a temperature control method for an inspection system, and an inspection system, for inspecting a substrate while performing temperature control to suppress an overshoot of a junction temperature of an electronic device, can be provided.

Brief Description of the Drawings

[0007]

FIG. 1 is an example of a perspective view of an inspection system.

FIG. 2 is an example of a configuration diagram of the inspection system.

FIG. 3 is an example of a plan view schematically showing a configuration of a substrate.

FIG. 4 is an example of an enlarged view of the inspection system, showing an enlarged region near an electronic device.

FIG. 5 is an example of a drawing showing a heat flow model.

FIG. 6 is an example of a block diagram for explaining state estimation by an observer.

FIG. 7 is an example of a block diagram for explaining state feedback.

FIG. 8 is a drawing showing a model of a stage temperature and a junction temperature of an electronic device.

FIG. 9 is a flowchart for explaining an example of a method for controlling a junction temperature of an electronic device.

FIG. 10 is a graph showing an example of temperature control of a stage temperature and a junction temperature of an electronic device.

Detailed Description

[0008]

Hereinafter, various exemplary embodiments will be described in detail with reference to the drawings. In each of the drawings, identical or equivalent parts are denoted by the same reference signs.

[0009]

An inspection system 1, which is an example of the inspection system according to the present embodiment, will be described with reference to FIG. 1. FIG. 1 is an example of a perspective view of the inspection system 1. FIG. 2 is an example of a configuration diagram of the inspection system 1. In FIG. 2, components built into the inspection system 1 are schematically shown, partially in cross-section.

[0010]

In a semiconductor manufacturing process, a plurality of electronic devices D (see FIG. 3 described later; also referred to as a "die") having a predetermined circuit pattern are formed on a substrate W, such as a semiconductor wafer. The formed electronic devices D are inspected for electrical characteristics and the like, and are sorted into non-defective products and defective products. The inspection of the electronic devices D is performed, for example, using the inspection system 1, with the substrate W in a state before each electronic device D is singulated.

[0011]

The inspection system 1 inspects the electrical characteristics of a plurality

of electronic devices D (see FIG. 3, described later) formed on the substrate W while performing temperature control. That is, the inspection system 1 supplies inspection power to the electronic devices D in a state where the electronic devices D are at or above a predetermined inspection temperature, and inspects the electrical characteristics and the like at that time.

[0012]

The inspection system 1 comprises an accommodation chamber 2, a loader 3, and a tester 4.

[0013]

The accommodation chamber 2 has a housing 11 with a hollow interior. The accommodation chamber 2 has, inside the housing 11, a stage 10 (also referred to as a "chuck") on which the substrate W is mounted. The stage 10 has a suction holding unit (not shown) that holds the substrate W by suction so that the relative position of the substrate W with respect to the stage 10 does not shift. The accommodation chamber 2 also has, inside the housing 11, a moving mechanism (not shown) for moving the stage 10 in a horizontal direction and a vertical direction. This moving mechanism allows the relative position of the substrate W and a probe card 12, described later, to be adjusted, so that a desired electrode part E (see FIG. 3, described later) on the surface of the substrate W can be brought into contact with a probe 12a of the probe card 12.

[0014]

The accommodation chamber 2 has a probe card 12 inside the housing 11. The probe card 12 is arranged above the stage 10 so as to face the stage 10. The probe card 12 comprises a plurality of needle-shaped probes 12a arranged in correspondence with electrode pads or solder bumps, which are provided in correspondence with the electrode part E of each electronic device D of the

substrate W. The probe card 12 is connected to the tester 4 via an interface 13. At the time of inspection of electrical characteristics, each probe 12a contacts the electrode part E of each electronic device D of the substrate W, supplies power from the tester 4 to the electronic device D via the interface 13, and also transfers a signal from the electronic device D to the tester 4 via the interface 13.

[0015]

A Front Opening Unify Pod (FOUP), which is a transfer container accommodating a substrate W, is arranged in the loader 3. The loader 3 also has a transfer mechanism (not shown) for transferring the substrate W. The transfer mechanism takes out the substrate W accommodated in the FOUP and transfers the substrate W to the stage 10 of the accommodation chamber 2. The transfer mechanism also receives the substrate W, for which the inspection of the electrical characteristics of the electronic device D has been completed, from the stage 10 and accommodates the substrate W in the FOUP.

[0016]

The tester 4 has a test board (not shown) that reproduces a part of the circuit configuration of a motherboard on which the electronic device D is mounted. The test board of the tester 4 is also connected to a tester computer 15 that determines whether the electronic device D is acceptable, based on a signal from the electronic device D. In the tester 4, the circuit configurations of a plurality of types of motherboards can be reproduced by replacing the test board. In addition, a plurality of probes 12a of the probe card 12 are provided, and are respectively brought into contact with a plurality of electrode parts E of the electronic device D. The tester 4 also has a plurality of detection means for detecting electrical characteristics of the electronic device D. Thereby, the tester 4 detects a plurality of electrical characteristics of the electronic device D.

[0017]

The inspection system 1 also comprises a user interface unit 16 for displaying information to a user or receiving an instruction from the user. The user interface unit 16 is composed of, for example, an input unit such as a touch panel or a keyboard, and a display unit such as a liquid crystal display.

[0018]

Thus, the inspection system 1 includes the stage 10 as a substrate holding unit that holds the substrate W. The inspection system 1 also includes, as a detection unit that detects electrical characteristics of the electronic device D by supplying inspection power to the electrode part E of the electronic device D provided on the substrate W, a probe card 12 having a probe 12a, an interface 13, and a tester 4.

[0019]

The loader 3 also has a temperature controller 14. The temperature controller 14 has a power supply 25, a chiller 26, a power supply 55, and a controller 90.

[0020]

The stage 10 is provided with a heater 20 (heating unit) for heating the stage 10. The power supply 25 supplies power to the heater 20 provided in the stage 10. A coolant flow path 10a through which a heat transfer medium (antifreeze or the like) flows is also formed inside the stage 10. The chiller 26 circulates the temperature-adjusted heat transfer medium through the coolant flow path 10a. Thus, the inspection system 1 includes, as a holding unit temperature control mechanism for adjusting a temperature of the substrate holding unit, the heater 20, the power supply 25, the coolant flow path 10a, and the chiller 26. The configuration of the holding unit temperature control mechanism, however, is not

limited to this. Also, although the heating unit for heating the stage 10 has been described as being the heater 20, the heating unit is not limited to this. The heating unit for heating the stage 10 may be a light source, such as an LED, that heats the stage 10 by irradiating light onto the stage 10 on which the substrate W is mounted.

[0021]

The holding unit temperature control mechanism also comprises a temperature detection unit 30 for detecting a temperature of the substrate holding unit. The temperature detection unit 30 is provided on the stage 10 and detects a temperature T_{chuck} of the stage 10. The temperature T_{chuck} of the stage 10 detected by the temperature detection unit 30 is input to the controller 90. Although the temperature detection unit 30 has been described as being singular in the drawing, the present disclosure is not limited thereto, and it is preferable to provide a plurality of temperature detection units 30 on the stage 10 for the electronic device D that generates heat upon receiving power. Also, when switching the electronic device D that generates heat upon receiving power, it is preferable to also switch the temperature detection unit 30 that detects the temperature T_{chuck}. Further, it is preferable to detect the temperature T_{chuck} based on a model that includes a plurality of temperature detection units 30.

[0022]

The tester 4 is also provided with a temperature control mechanism 50 that regulates a temperature of the probe card 12. The temperature control mechanism 50 may include a heater (not shown) for heating the probe card 12, a cooling fan (not shown) for air-cooling the probe card 12, and the like. The power supply 55 supplies power to the temperature control mechanism 50 provided in the tester 4. Thus, the inspection system 1 includes, as a detection unit temperature

control mechanism for adjusting a temperature of the detection unit, the temperature control mechanism 50. The configuration of the detection unit temperature control mechanism, however, is not limited to this. The detection unit temperature control mechanism may include a configuration that adjusts the temperature of the detection unit by liquid cooling.

[0023]

The detection unit temperature control mechanism also comprises a temperature detection unit 60 for detecting a temperature of the detection unit. The temperature detection unit 60 is provided on the probe card 12 and detects a temperature T_{prob} of the probe card 12. The temperature T_{prob} of the probe card 12 detected by the temperature detection unit 60 is input to the controller 90. Although the temperature detection unit 60 has been described as being provided on the probe card 12, the present disclosure is not limited thereto, and the temperature detection unit 60 may be any temperature detection unit capable of detecting a temperature representative of a temperature of a probe. For example, the temperature detection unit 60 may be a temperature detection unit that detects a temperature of the probe 12a. Also, although the temperature detection unit 60 has been described as being singular in the drawing, the present disclosure is not limited thereto, and it is preferable to provide a plurality of temperature detection units 60 on the probe card 12 for the electronic device D that generates heat upon receiving power. Furthermore, when switching the electronic device D that generates heat upon receiving power, it is preferable to also switch the temperature detection unit 60 that detects the temperature T_{prob}. Furthermore, it is preferable to detect the temperature T_{prob} based on a model that includes a plurality of temperature detection units 60.

[0024]

The tester 4 also has a power detection unit 41 that detects inspection power (electric current and voltage) supplied from the tester 4 to the electronic device D through the interface 13 and the probe card 12. The inspection power detected by the power detection unit 41 is input to the controller 90.

[0025]

The controller 90 has a holding unit temperature controller 91, a detection unit temperature controller 92, and an analysis unit 93. The controller 90 controls the holding unit temperature control mechanism and the detection unit temperature control mechanism such that a junction temperature T_j of the electronic device D (the temperature of the substrate W) becomes the inspection temperature. The controller 90 also controls the holding unit temperature control mechanism and the detection unit temperature control mechanism such that a temperature difference between the substrate W and the probe card 12 is within a predetermined threshold value.

[0026]

The holding unit temperature controller 91 controls the holding unit temperature control mechanism such that the temperature T_{chuck} of the substrate holding unit detected by the temperature detection unit 30 becomes a target temperature. Although the temperature detection unit 30 has been described as being singular in the drawing, the present disclosure is not limited to this, and it is preferable to provide a plurality of temperature detection units 30 on the stage 10 for the electronic device D that generates heat upon receiving power. Also, when switching the electronic device D that generates heat upon receiving power, it is preferable to also switch the temperature detection unit 30 that detects the temperature T_{chuck}. Further, it is preferable to detect the temperature T_{chuck} based on a model that includes a plurality of temperature detection units 30. That is, the

holding unit temperature controller 91 controls the temperature T_{chuck} of the stage 10 by controlling the power supply 25 to control a heat generation amount of the heater 20. The holding unit temperature controller 91 may also control the temperature T_{chuck} of the stage 10 by controlling the chiller 26 to control a temperature of the heat transfer medium that the chiller 26 supplies to the coolant flow path 10a.

[0027]

The detection unit temperature controller 92 controls the detection unit temperature control mechanism such that the temperature T_{prob} detected by the temperature detection unit 60 becomes a target temperature. That is, the detection unit temperature controller 92 controls the power supply 55 to control the temperature control mechanism 50, thereby controlling the temperature T_{prob} of the probe card 12. Although the temperature detection unit 60 has been described as being singular in the drawing, the present disclosure is not limited thereto, and it is preferable to provide a plurality of temperature detection units 60 on the probe card 12 for the electronic device D that generates heat upon receiving power. Also, when switching the electronic device D that generates heat upon receiving power, it is preferable to also switch the temperature detection unit 60 that detects the temperature T_{prob}. Further, it is preferable to detect the temperature T_{prob} based on a model that includes a plurality of temperature detection units 60.

[0028]

The analysis unit 93 estimates a junction temperature T_j (temperature of the substrate W) of the electronic device D based on the heat flow model shown in FIG. 5, described later. The controller 90 then adjusts the Chuck Heat Flux (see heat flow I_c, described later with reference to FIG. 5) such that the temperature T_{chuck} becomes a target temperature (holding unit target temperature). The

controller 90 may also be configurated to adjust the Chuck Heat Flux (see heat flow I_c, described later with reference to FIG. 5) such that the temperature T_{chuck} becomes the target temperature (holding unit target temperature), and to adjust the Probe Heat Flux (see heat flow I_p, described later with reference to FIG. 5) so that the temperature T_{prob} becomes the target temperature (detection unit target temperature). The holding unit temperature controller 91 controls the holding unit temperature control mechanism based on the holding unit target temperature calculated by the analysis unit 93. The detection unit temperature controller 92 also controls the detection unit temperature control mechanism based on the detection unit target temperature calculated by the analysis unit 93. Here, there are a plurality of solutions for the holding unit target temperature and the detection unit target temperature calculated by the analysis unit 93. In practice, about 40% of heat is also radiated from the electronic device D to the probe card 12. The amount of heat absorbed by the probe card 12 from the electronic device D has a trade-off relationship with a difference in thermal expansion between the probe card 12 and the substrate W. The amount of heat absorbed by the probe card 12 from the electronic device D is calculated as the amount of heat absorbed within the range in which the probe 12a contacts the bonding pad (electrode part E).

[0029]

Next, the substrate W to be inspected in the above-described inspection system 1 will be described with reference to FIG. 3. FIG. 3 is a plan view schematically showing a configuration of the substrate W.

[0030]

As shown in FIG. 3, a plurality of electronic devices D are formed to be spaced apart from each other at a predetermined interval by performing an etching process or a wiring process on the surface of the substrate W, which is a

substantially disc-shaped silicon substrate. An electrode part E is formed on the surface of the electronic device D, that is, the substrate W, and the electrode part E is electrically connected to a circuit element inside the electronic device D. By applying a voltage to the electrode part E, an electric current can be caused to flow through the circuit element inside each electronic device D.

[0031]

FIG. 4 is an example of an enlarged view of the inspection system 1, showing an enlarged region near the electronic device D.

[0032]

When an inspection of the electrical characteristics or the like of the electronic device D is performed, the substrate W is held on the stage 10. That is, the electronic device D is thermally connected to the stage 10. Also, when an inspection of an electrical characteristic or the like of the electronic device D is performed, the probe 12a is in contact with the electrode part E of the electronic device D. That is, the electronic device D is thermally connected to the probe card 12 via the probe 12a. Further, the probe card 12 is in contact with the interface 13, and the interface 13 is in contact with the tester 4. That is, the probe card 12 is thermally connected to the tester 4 via the interface 13, and the tester 4 is thermally connected to the electronic device D via the probe card 12.

[0033]

The temperature T_{chuck} of the stage 10 is detected by the temperature detection unit 30. The temperature T_{prob} of the probe card 12 is also detected by the temperature detection unit 60.

[0034]

Here, the junction temperature T_j of the electronic device D can be detected from a correlation between an electromotive force generated by passing an electric

current through a PN junction (e.g., a transistor) formed in the electronic device D, and a temperature. However, when an inspection of the electronic device D, such as a logic IC, is performed, for example, there are cases where, under a condition in which a clock is being generated, the junction temperature T_j cannot be properly detected due to the influence of noise or the like.

[0035]

When the inspection of the electronic device D is performed, a temperature difference occurs between the temperature T_{chuck} of the stage 10 and the junction temperature T_j of the electronic device D, due to thermal resistance between the stage 10 and the substrate W (the electronic device D). For this reason, when the inspection of the electronic device D is performed while controlling the temperature T_{chuck} of the stage 10 to be the inspection temperature, there is a risk that the junction temperature T_j of the electronic device D will become higher than the inspection temperature. That is, the inspection of the electronic device D is performed at a temperature higher than the inspection temperature, and there is a risk that the yield of the electronic device D will decrease.

[0036]

Also, when an inspection of the electronic device D is performed while controlling the temperature T_{chuck} of the stage 10 to be the inspection temperature, a heat flow from the electronic device D to the detection unit becomes a disturbance.

[0037]

The substrate W is, for example, formed mainly of silicon. The probe card 12 is, for example, formed mainly of glass epoxy. A difference in thermal expansion occurs due to a temperature difference between the substrate W and the probe card 12, and there is a risk that the probe 12a may be displaced from the

electrode part E.

[0038]

Next, temperature control in the inspection system 1 according to the present embodiment will be described. FIG. 5 is an example of a drawing showing a heat flow model.

[0039]

In FIG. 5, the heat flow I_d, the thermal resistance R_d, the heat capacity C_d, and the junction temperature T_j of the electronic device D are shown. Also, the heat flow I_p of the probe card 12, the thermal resistance R_p of the probe card 12, the heat capacity C_p of the probe card 12, the temperature of the probe card 12 (probe card temperature) T_{prob}, the heat flow I_{dp} from the probe card 12 to the electronic device D, and the thermal resistance R_{dp} from the probe card 12 to the electronic device D are shown. Further, the heat flow I_c of the stage 10, the thermal resistance R_c of the stage 10, the heat capacity C_c of the stage 10, the temperature of the stage 10 (chuck temperature) T_{chuck}, the heat flow I_{dc} from the stage 10 to the electronic device D, and the thermal resistance R_{dc} from the stage 10 to the electronic device D are shown. In FIG. 5, although the temperature detection unit 30 (see FIGS. 2 and 4) for detecting the temperature T_{chuck} has been described as being singular, performance is further improved by arranging a plurality of temperature detection units 30 and switching between them, or by detecting the temperature T_{chuck} based on a model that includes a plurality of temperature detection units 30.

[0040]

Here, the various thermal resistances and various heat capacities are values (acquirable values) that are predetermined according to the configurations of the substrate holding unit, the substrate W, the detection unit, and the like.

[0041]

The heat flow I_d of the electronic device D corresponds to a heat flow due to the inspection power detected by the power detection unit 41. The heat flow I_c of the stage 10 corresponds to a heat flow in the holding unit temperature control mechanism. The heat flow I_p of the probe card 12 corresponds to a heat flow in the detection unit temperature control mechanism. That is, the heat flows I_d, I_c, and I_p are values that are detectable by the controller 90.

[0042]

Also, the temperature of the stage 10 (chuck temperature) T_{chuck} corresponds to a temperature detected by the temperature detection unit 30. The temperature of the probe card 12 (probe card temperature) T_{prob} corresponds to a temperature detected by the temperature detection unit 60. That is, the temperatures T_{chuck} and T_{prob} are values that are detectable by the controller 90.

[0043]

On the other hand, the junction temperature T_j of the electronic device D is a temperature that cannot be directly measured by the controller 90.

[0044]

In the heat flow model shown in FIG. 5, a derivative value of the junction temperature T_j (T_j dot), a derivative value of the temperature T_{prob} of the probe card 12 (T_{prob} dot), and a derivative value of the temperature T_{chuck} of the stage 10 (T_{chuck} dot) can be represented by the following equation:

[0045]

[Equation 1]

$$\dot{T}_j = \frac{\dot{Q}_d}{C_d} = \frac{1}{C_d}\left(i_{dp} + i_{dc} + i_d\right) = \frac{i_{dp}}{C_d} + \frac{i_{dc}}{C_d} + \frac{i_d}{C_d}$$
$$= \frac{1}{C_d}\left(T_{chuck} - T_j\right) + \frac{1}{C_d}\left(T_{prob} - T_j\right) + \frac{i_d}{C_d}$$

$$\dot{T}_{chuck} = \frac{\dot{Q}_c}{C_c} = \frac{i_c}{C_c} - \frac{1}{C_c \cdot R_{dp}}\left(T_{chuck} - T_j\right)$$

$$\dot{T}_{prob} = \frac{\dot{Q}_p}{C_p} = \frac{i_p}{C_p} - \frac{1}{C_p \cdot R_{dc}}\left(T_{prob} - T_j\right)$$

[0046]

Here, if $X_1=T_j$, $X_2=T_{chuck}$, $X_3=T_{prob}$, $U_1=i_d$, $U_2=i_c$, and $U_3=i_p$, it can be represented by the following equation:

[0047]

[Equation 2]

$$\begin{bmatrix}\dot{X}_1\\ \dot{X}_2\\ \dot{X}_3\end{bmatrix} = \begin{bmatrix} -\frac{2}{C_d} & \frac{1}{C_d} & \frac{1}{C_d} \\ -\frac{1}{C_c \cdot R_{dp}} & \frac{1}{C_c \cdot R_{dp}} & 0 \\ -\frac{1}{C_p \cdot R_{dc}} & 0 & \frac{1}{C_p \cdot R_{dc}} \end{bmatrix}\begin{bmatrix}X_1\\ X_2\\ X_3\end{bmatrix} + \begin{bmatrix}\frac{1}{C_d} & \frac{1}{C_c} & \frac{1}{C_p}\end{bmatrix}\begin{bmatrix}U_1\\ U_2\\ U_3\end{bmatrix}$$

$$\begin{bmatrix}Y_1\\ Y_2\\ Y_3\end{bmatrix} = \begin{bmatrix}0 & 1 & 1\end{bmatrix}\begin{bmatrix}X_1\\ X_2\\ X_3\end{bmatrix}$$

[0048]

That is, the above-described equation is represented as dx/dt=Ax(t)+Bu(t) and y(t)=Cx(t).

[0049]

FIG. 6 is an example of a block diagram illustrating state estimation by an observer. The block diagram 600 includes a controlled object 610 and an observer 620. The controlled object 610 corresponds to the above-described equation. Here, x(t) is a value that cannot be measured. By using the observer 620, an estimated value of x(t) can be calculated (in FIG. 6, a hat (^) is attached to the estimated value obtained by the observer 620).

[0050]

That is, in the heat flow model shown in FIG. 5, the analysis unit 93 can estimate the junction temperature T_j of the electronic device D, which cannot be directly measured, by using the observer 620 shown in FIG. 6.

[0051]

FIG. 7 is an example of a block diagram for explaining state feedback. The block diagram 700 includes an integral controller 710, an operator 720, a controlled object 730, an operator 740, and an operator 750. The controlled object 730 shown in FIG. 7 includes an observer, similarly to the block diagram 600 shown in FIG. 6, but the observer is omitted from the illustration. An estimated value of x(t) estimated by the observer is input to the integral controller 710 and the operator 740.

[0052]

The integral controller 710 performs state feedback of the estimated value of x(t) estimated by the observer.

[0053]

Here, an estimated value (X_1 hat) of X_1 estimated by the observer is defined as Y_1. That is, Y_1 is the junction temperature T_j estimated by the observer. A difference between the estimated value (X_1 hat) of X_1 estimated by the observer and X_3 is defined as Y_2. That is, Y_2 is a difference between the junction temperature T_j estimated by the observer and the temperature T_{prob}, and is an estimated value of a temperature difference between the substrate W (electronic device D) and the probe card 12. These can be represented by the following equation:

[0054]

[Equation 3]

$$\begin{bmatrix} \widehat{Y_{m1}} \\ \widehat{Y_{m2}} \\ \widehat{Y_{m3}} \end{bmatrix} = Ac \cdot \widehat{\mathrm{X}} = \begin{bmatrix} 1 & 0 & 0 \\ 1 & 0 & -1 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \widehat{\mathrm{X}_1} \\ \widehat{\mathrm{X}_2} \\ \widehat{\mathrm{X}_3} \end{bmatrix}.$$

[0055]

The operator 740 feeds back an estimated value (Y_m hat) of Y_m to the operator 750 according to the above-described equation.

[0056]

Accordingly, feedback is provided for the junction temperature T_j and the difference between the junction temperature T_j and the temperature T_{prob}.

[0057]

The integral controller 710 is also preferably configured such that Y_2 is faster than Y_1.

[0058]

As described above, the controller 90 inspects the substrate W while adjusting the temperature control performed by the holding unit temperature control mechanism and the detection unit temperature control mechanism.

[0059]

Specifically, the controller 90 can inspect the substrate W while adjusting the temperature (junction temperature T_j) of the substrate W, by acquiring and comprehensively analyzing the heat flow I_d due to the inspection power output when the inspection power is supplied, the heat flow I_c in the holding unit temperature control mechanism, and the heat flow I_p in the detection unit temperature control mechanism. As a result, when the electronic device D is inspected, the electronic device D can be brought to the inspection temperature, and the inspection can be performed appropriately. Also, a decrease in the yield of the electronic device D can be prevented.

[0060]

The controller 90 can also perform the inspection of the substrate W while adjusting a temperature difference between the temperature of the substrate W (junction temperature T_j) and the temperature of the detection unit (temperature T_{prob}), by acquiring and comprehensively analyzing the heat flow I_d due to the inspection power output when the inspection power is supplied, the heat flow I_c in the holding unit temperature control mechanism, and the heat flow I_p in the detection unit temperature control mechanism. As a result, a difference in thermal expansion between the substrate W and the probe card 12 is suppressed, thereby preventing the probe 12a from deviating from the electrode part E. Also, friction between the probe 12a and the electrode part E can be suppressed to a minimum.

[0061]

The analysis unit 93 of the controller 90 can also estimate the junction temperature T_j of the electronic device D based on the heat flow I_d due to the inspection power, the heat flow I_c in the holding unit temperature control mechanism, the heat flow I_p in the detection unit temperature control mechanism, the temperature T_{chuck} of the substrate holding unit, and the temperature T_{prob} of the detection unit. As a result, compared to a configuration in which an electrode part E used only for detecting the junction temperature T_j is provided in the electronic device, the package cost of the electronic device D can be reduced. Also, the number of probes 12a provided on the probe card 12 can be reduced.

[0062]

Further, the heat flow I_d due to the inspection power is obtained, for example, from the inspection power detected by the power detection unit 41. The heat flow I_c in the holding unit temperature control mechanism is obtained, for example, from the input power of the power supply 25. The heat flow I_p in the

detection unit temperature control mechanism is obtained, for example, from the input power of the power supply 55.

[0063]

The controller 90 also controls the holding unit temperature control mechanism and the detection unit temperature control mechanism such that the junction temperature T_j becomes the inspection temperature. As a result, when the electronic device D is inspected, the junction temperature T_j of the electronic device D can be set to the inspection temperature, so that the inspection can be performed appropriately. Also, a decrease in the yield of the electronic device D can be prevented.

[0064]

The controller 90 also controls the holding unit temperature control mechanism and the detection unit temperature control mechanism such that a temperature difference between the substrate W and the probe card 12 is within a predetermined threshold value. As a result, a difference in thermal expansion is suppressed, thereby preventing the probe 12a from deviating from the electrode part E. Also, friction between the probe 12a and the electrode part E can be suppressed.

[0065]

The analysis unit 93 of the controller 90 also calculates a holding unit target temperature and a detection unit target temperature, based on the heat flow I_d due to the inspection power, the heat flow I_c in the holding unit temperature control mechanism, the heat flow I_p in the detection unit temperature control mechanism, the temperature T_{chuck} of the substrate holding unit, and the temperature T_{prob} of the detection unit.

[0066]

The holding unit temperature controller 91 controls the temperature of the substrate holding unit to a holding unit target temperature. In other words, the holding unit temperature controller 91 controls the power supply 25 of the heater 20 and/or the chiller 26 such that the temperature T_{chuck} detected by the temperature detection unit 30 approaches the holding unit target temperature. The detection unit temperature controller 92 also controls the temperature of the detection unit to a detection unit target temperature. In other words, the detection unit temperature controller 92 controls the power supply 55 of the temperature control mechanism 50 such that the temperature T_{prob} detected by the temperature detection unit 60 approaches the detection unit target temperature.

[0067]

Here, the holding unit target temperature and the detection unit target temperature are set such that the estimated junction temperature T_j approaches the inspection temperature. As a result, when the electronic device D is inspected, the junction temperature T_j of the electronic device D can be set to the inspection temperature, so that the inspection can be performed appropriately. Also, a decrease in the yield of the electronic device D can be prevented.

[0068]

Also, the holding unit target temperature and the detection unit target temperature are set such that a difference between the estimated junction temperature T_j and the temperature T_{prob} of the probe card 12 is less than or equal to a threshold value. This suppresses a difference in thermal expansion, thereby preventing the probe 12a from deviating from the electrode part E. Also, friction between the probe 12a and the electrode part E can be suppressed.

[0069]

Next, a model of the temperature T_{chuck} of the stage 10 and the junction

temperature T_j of the electronic device D will be described with reference to FIG. 8. FIG. 8 is a drawing showing a model of the temperature T_{chuck} of the stage 10 and the junction temperature T_j of the electronic device D. In FIG. 8, the inflow and outflow of heat are represented as the inflow and outflow of a fluid.

[0070]

A heat tank 801 represents the heat capacity of the stage 10. The water level of the heat tank 801 corresponds to the temperature T_{chuck}. A heat tank 802 represents the heat capacity of the electronic device D. The water level of the heat tank 802 corresponds to the junction temperature T_j. A heat flow path 803 connecting the heat tank 801 and the heat tank 802 corresponds to heat transfer between the stage 10 and the electronic device D. A narrowness of the cross-sectional area of the flow path of the heat flow path 803 corresponds to the thermal resistance R_{dc} between the stage 10 and the electronic device D.

[0071]

A heat inflow part 804 to the heat tank 801 corresponds to a heat generation amount of the heater 20 (heating unit) that heats the stage 10. A heat inflow part 805 to the heat tank 802 corresponds to a heat generation amount due to the inspection power (the inspection power detected by the power detection unit 41) supplied to the electronic device D. A heat outflow part 806 from the heat tank 801 corresponds to an amount of heat radiated from the stage 10 to the atmosphere. A heat outflow part 807 from the heat tank 801 corresponds to an amount of heat radiated from the stage 10 to the chiller 26. A high-speed valve 808, which can be opened and closed at high speed, is provided in the heat outflow part 807 between the heat tank 801 and the chiller 809. By controlling the high-speed valve 808, the amount of heat radiated from the stage 10 to the chiller 26 is controlled.

[0072]

Here, to evaluate the characteristics of the electronic device D on the substrate W, the substrate W is held on the stage 10 by vacuum suction, inspection power is supplied to the electronic device D, and an inspection of the electronic device D is performed. As the heat generation density of the electronic device D rises, the thermal resistance between the electronic device D and the stage 10 (corresponding to the cross-sectional area of the flow path of the thermal flow path 803 shown in FIG. 8) becomes non-negligible. Due to the thermal resistance between the electronic device D and the stage 10, the temperature difference between the electronic device D and the stage 10 at the time of the inspection may be on the order of several tens of °C. That is, the inspection of the electronic device D is performed at a temperature higher than the inspection temperature, and there is a risk that the yield of the electronic device D will decrease.

[0073]

In contrast, as shown in FIGS. 4 to 7, an inspection can be performed appropriately by estimating the junction temperature T_j. However, even in this case, when the temperature T_{chuck} of the stage 10 is controlled such that the junction temperature T_j reaches a predetermined temperature, there is a risk that the junction temperature T_j may overshoot the predetermined temperature due to the thermal resistance between the electronic device D and the stage 10.

[0074]

FIG. 9 is an example of a flowchart for explaining a method for controlling the junction temperature T_j of the electronic device D.

[0075]

In step S101, a first transfer function of a rise in Die temperature caused by Die heat generation during an inspection is modeled and obtained. Here, the

controller 90 models and obtains the first transfer function, which represents a relationship between heat generation (Die heat generation) caused by supplying inspection power to the electronic device D (Die) and a rise in the junction temperature T_j (Die temperature) of the electronic device D. The first transfer function is also obtained based on data acquired by simulation, experiment, or the like.

[0076]

In step S102, a second transfer function of the chuck temperature when a chuck set temperature is changed is modeled and obtained. Here, the controller 90 models and obtains a second transfer function representing a change in the temperature T_{chuck} of the stage 10 (chuck temperature) from a set temperature before the change to a set temperature after the change, when the set temperature of the stage 10 (chuck set temperature) is changed. The second transfer function is also obtained based on data acquired by simulation, experiment, or the like.

[0077]

Here, the inspection temperature (junction temperature T_j) of the electronic device D during an inspection is set to a first set temperature T1. The chuck set temperature before the start of the inspection is set to the first set temperature T1. As a result, the temperature of the electronic device D mounted on the stage 10 is also set to the first set temperature T1. On the other hand, during the inspection, the electronic device D generates heat as inspection power is supplied thereto. For this reason, by setting the chuck set temperature during the inspection to a second set temperature T2, which is lower than the first set temperature T1, the inspection temperature (junction temperature T_j) of the electronic device D during the inspection is brought close to the first set temperature T1.

[0078]

In step S103, the chuck set temperature at the time of the inspection is calculated. Here, the controller 90 sets a set temperature after the change (the chuck set temperature at the time of the inspection, a second set temperature T2: T2=T1-ΔT) to a value obtained by subtracting a rise (temperature difference ΔT) in the junction temperature T_j (Die temperature) of the electronic device D, when the inspection power is supplied to the electronic device D (Die) in step S101, from a set temperature before the change (a first set temperature T1).

[0079]

In step S104, a reference response waveform of the chuck temperature is calculated. Here, the controller 90 calculates a reference response waveform of the chuck temperature (a profile of a reference temperature change) for changing the temperature from the first set temperature T1 to the second set temperature T2, such that the junction temperature T_j of the electronic device D does not overshoot and/or undershoot.

[0080]

In step S105, a reference value of the Die power is acquired. Here, the controller 90 acquires information such as the inspection power (Die power) for inspecting the electronic device D, from the tester 4. In the inspection of the electronic device D, the heat generation amount of each electronic device D also differs depending on characteristics or the like of each electronic device D. For this reason, in step S105, a reference value of the inspection power (a reference value of the Die power), which is an approximate value of the inspection power of the electronic device D, is acquired.

[0081]

In step S106, a target trajectory of the chuck temperature is created. Here, the controller 90 creates a target trajectory of the chuck temperature based on the

reference value of the inspection power (the reference value of the Die power) obtained in step S105, the first transfer function obtained in step S101, the second transfer function obtained in step S102, and the reference response waveform obtained in step S104.

[0082]

In step S107, the chuck temperature is controlled. Here, the controller 90 controls the temperature T_{chuck} (chuck temperature) of the stage 10 from the first set temperature T1 to the second set temperature T2, based on the target trajectory of the chuck temperature created in step S106.

[0083]

In step S108, the Die power is applied to start the inspection, and power following control is performed. Here, the controller 90 applies the inspection power (Die power) to the electronic device D to start the inspection of the electronic device D, and introduces the inspection power (Die power) into the control model to perform control (power following control) by feedforward control, such that the temperature T_{chuck} (chuck temperature) of the stage 10 becomes the second set temperature T2.

[0084]

In step S109, the junction temperature T_j is controlled. Here, the controller 90 controls the junction temperature T_j such that it becomes the first set temperature T1.

[0085]

Although it has been described that, after inspection power is applied to the electronic device D that is an inspection target, the temperature T_{chuck} (chuck temperature) of the stage 10 is controlled to the second set temperature T2 based on the inspection power in step S108, and then the junction temperature T_j of the

stage 10 of the electronic device D is controlled to the first set temperature T1 based on the inspection power in step S109, the present disclosure is not limited thereto. Step S108 and step S109 may be combined into a single step, in which, after the inspection power is applied to the electronic device D that is the inspection target, the junction temperature T_j of the stage 10 of the electronic device D is controlled to the first set temperature T1 based on the inspection power. That is, the junction temperature T_j estimated from the control model, or, when it can be directly observed, the directly observed junction temperature T_j, is controlled such that it becomes the target temperature (the first set temperature T1) of the electronic device D. At this time, the inspection power applied to the electronic device D may be controlled as a disturbance.

[0086]

FIG. 10 is a graph showing an example of temperature control of the temperature T_{chuck} of the stage 10 and the junction temperature T_j of the electronic device D. Here, the horizontal axis represents time (sec), and the vertical axis represents temperature. The junction temperature T_j of the electronic device D is represented by a solid line, and the temperature T_{chuck} of the stage 10 is represented by a dashed line. It is described on the assumption that the processing of steps S101 to S104 has already been completed.

[0087]

In step S201, the controller 90 controls the temperature T_{chuck} of the stage 10 such that it becomes the first set temperature T1. Also, in step S201, no inspection power is applied to the electronic device D. As a result, the temperature T_{chuck} of the stage 10 and the junction temperature T_j of the electronic device D are at the first set temperature T1.

[0088]

At time point ST0 of step S201, the controller 90 acquires information regarding the inspection of the electronic device D from the tester 4 (see step S105). Here, the information regarding the inspection includes information on a time t_{imp} until the start of the inspection of the electronic device D (a time from the time point ST0, at which the information regarding the inspection is acquired, to the time point ST2 at which the inspection is started), and a reference value of the inspection power supplied to the electronic device D at the time of the inspection.

[0089]

Here, the controller 90 generates a target trajectory of the temperature T_{chuck} (chuck temperature) of the stage 10, based on the information acquired from the tester 4 (see step S106). The controller 90 calculates an amount of temperature rise (temperature difference ΔT) based on a reference value of the inspection power supplied to the electronic device D at the time of the inspection, and the first transfer function model generated in step S101. The controller 90 then sets a value, obtained by subtracting the amount of temperature rise (temperature difference ΔT) from the first set temperature T1, as a second set temperature T2 (T2=T1-ΔT). The controller 90 then generates a target trajectory for changing the temperature T_{chuck} (chuck temperature) of the stage 10 from the first set temperature T1 to the second set temperature T2, based on the second transfer function model generated in step S102 and the reference response waveform generated in step S104. The controller 90 also determines a response time t for changing the temperature T_{chuck} (chuck temperature) of the stage 10 from the first set temperature T1 to the second set temperature T2, from the generated target trajectory.

[0090]

The controller 90 also generates a target trajectory for changing the

temperature T_{chuck} (chuck temperature) of the stage 10 from the second set temperature T2 to the first set temperature T1.

[0091]

At a time point ST1, at which a time t_{imp}-t has elapsed from a time point ST0 at which information regarding the inspection was acquired from the tester 4, that is, at the time point ST1 preceding, by the response time t, a time point ST2 at which the inspection is started, the temperature control of the temperature T_{chuck} (chuck temperature) of the stage 10, according to the target trajectory, is started (see step S107).

[0092]

In step S202 (step S107), the temperature T_{chuck} (chuck temperature) of the stage 10 is controlled according to the target trajectory generated in step S106. Also, in step S202, no inspection power is applied to the electronic device D. As a result, the temperature T_{chuck} (chuck temperature) of the stage 10 decreases from the first set temperature T1 to the second set temperature T2. The junction temperature T_j of the electronic device D also follows the temperature T_{chuck} of the stage 10 and decreases from the first set temperature T1 to the second set temperature T2.

[0093]

At time point ST2, the inspection of the electronic device D is started. That is, inspection power is applied to the electronic device D (see step S108). As a result, the junction temperature T_j of the electronic device D rises.

[0094]

In step S203 (step S108), the inspection power (Die power) is introduced into the control model, and the temperature T_{chuck} (chuck temperature) of the stage 10 is controlled by feedforward control (power following control) such that it

becomes the second set temperature T2.

[0095]

After the transient period, in which the junction temperature T_j fluctuates, has passed, at time point ST3, the process proceeds from step S203 to step S204. Here, it may be determined that the transient period has passed after a predetermined time has elapsed from the time point ST2 at which the inspection of the electronic device D was started. Also, it may be determined that the transient period has passed when the amount of fluctuation of the junction temperature T_j falls within a predetermined range.

[0096]

In step S204 (step S109), the controller 90 controls the temperature such that the junction temperature T_j becomes the first set temperature T1.

[0097]

At time point ST4, the inspection of the electronic device D ends.

[0098]

In step S205, the temperature T_{chuck} (chuck temperature) of the stage 10 is controlled according to the target trajectory. Also, in step S205, no inspection power is applied to the electronic device D. As a result, the temperature T_{chuck} (chuck temperature) of the stage 10 rises from the second set temperature T2 to the first set temperature T1. As a result, the temperature T_{chuck} (chuck temperature) of the stage 10 and the junction temperature T_j of the electronic device D become the first set temperature T1.

[0099]

As described above, according to the control shown in FIGS. 9 and 10, overshoot and/or undershoot of the junction temperature T_j can be suppressed. That is, when the inspection power is applied to the electronic device D, fluctuation

of the junction temperature T_j of the electronic device D can be suppressed to within a predetermined range including the first set temperature T1 (for example, within a range of ±3°C of the temperature T1 (i.e., within the range of T1-3°C to T1+3°C)). That is, after the inspection power is applied to the electronic device D, the time until the junction temperature T_j is stabilized and the inspection is started can be shortened. Also, since the overshoot of the junction temperature T_j of the electronic device D can be suppressed, thermal destruction of the electronic device D can be prevented. Also, a decrease in the yield of the electronic device D can be prevented.

[0100]

Although the inspection system 1 has been described above, the present disclosure is not limited to the above-described embodiments and the like, and various modifications and improvements can be made within the scope of the gist of the present disclosure as described in the claims.

[0101]

This application claims priority based on Japanese Patent Application No. 2024-044178, filed on March 19, 2024, the entire contents of which are incorporated herein by reference.

Description of Reference Numerals

[0102]

W: substrate

D: electronic device

E: electrode part

1: inspection system

2: accommodation chamber

3: loader

4: tester

10: stage

10a: coolant flow path

12: probe card

12a: probe

13: interface

14: temperature controller

20: heater

25: power supply

26: chiller

30: temperature detection unit

41: power detection unit

50: temperature control mechanism

55: power supply

90: controller

91: holding unit temperature controller

92: detection unit temperature controller

93: analysis unit

60: temperature detection unit

CLAIMS

[Claim 1]

A temperature control method for an inspection system comprising a chuck that holds a substrate having an electronic device to be inspected, and a tester that inspects the electronic device by applying an inspection power to the electronic device, the method comprising:

modeling and obtaining a first transfer function of a temperature rise of the electronic device caused by heat generation resulting from applying the inspection power to the electronic device;

modeling and obtaining a second transfer function of a temperature of the chuck when a set temperature of the chuck is changed;

acquiring an inspection timing of the electronic device from the tester; and

starting temperature control of the chuck based on the first transfer function and the second transfer function before an inspection of the electronic device starts.

[Claim 2]

The temperature control method according to claim 1, wherein:

a temperature rise amount of the electronic device, when the inspection power is applied to the electronic device, is a temperature rise amount ΔT;

a set temperature of the electronic device when inspecting the electronic device is a first set temperature T1; and

a temperature obtained by subtracting the temperature rise amount ΔT from the first set temperature T1 is a second set temperature T2,

wherein, in said starting the temperature control of the chuck before the inspection of the electronic device starts, a temperature of the chuck is controlled from the first set temperature T1 to the second set temperature T2.

[Claim 3]

The temperature control method for an inspection system according to claim 2, comprising:

generating a target trajectory for controlling a temperature of the chuck from the first set temperature T1 to the second set temperature T2, and calculating a response time of the target trajectory;

wherein, in said starting temperature control of the chuck before the inspection of the electronic device starts, the temperature of the chuck is controlled from the first set temperature T1 to the second set temperature T2 based on the target trajectory, at a time preceding the inspection timing by the response time.

[Claim 4]

The temperature control method for an inspection system according to claim 3, further comprising controlling a temperature of the chuck to the second set temperature T2 based on the inspection power, after the inspection power is applied to the electronic device to be inspected.

[Claim 5]

The temperature control method for an inspection system according to claim 3, further comprising controlling a temperature of the electronic device to the first set temperature T1 based on the inspection power, after the inspection power is applied to the electronic device to be inspected.

[Claim 6]

The temperature control method for an inspection system according to claim 4, further comprising controlling a temperature of the electronic device to the first set temperature based on the inspection power, after the inspection power is applied to the electronic device to be inspected and after a transient period of a temperature change of the electronic device has passed.

[Claim 7]

An inspection system, comprising:

a chuck configured to hold a substrate having an electronic device to be inspected;

a tester configured to inspect the electronic device by applying an inspection power to the electronic device; and

a controller,

wherein the controller is configured to execute:

modeling and obtaining a first transfer function of a temperature rise of the electronic device caused by heat generation resulting from applying the inspection power to the electronic device;

modeling and obtaining a second transfer function of a temperature of the chuck when a set temperature of the chuck is changed;

acquiring an inspection timing of the electronic device from the tester; and

starting temperature control of the chuck based on the first transfer function and the second transfer function before an inspection of the electronic device starts.