CERTIFICATION

I, Naoko UNO, c/o Sakai International Patent Office, 5F, Toranomon Mitsui Building 8-1, Kasumigaseki 3-chome, Chiyoda-ku, Tokyo, 100-0013, Japan, do hereby certify that I am fluent in the English and Japanese languages and a competent translator thereof, and that to the best of my knowledge and belief the following is a true and correct translation of the accompanying Non-English Language Japanese Patent Application Laid-Open Publication No. JP03-196206 A.

I certify under penalty of perjury under the laws of the United States that the foregoing is true and correct.

Executed this 20th day of January, 2017.

Signature: Naoko Uno

Naoko Uno

Tokyo Electron Limited
EXHIBIT 1006

(19) JAPAN PATENT OFFICE (JP)

(11) PUBLICATION NUMBER

(12) PATENT APPLICATION LAID-OPEN PUBLICATION (A)

JP 3-196206 A

(51) Int.Cl^5	IDENTIFICATION CODE:	JPO REFERENCE NUMBER			
G05D 23/19	J	8835-5H			
G03F 7/26		7124-2H			
G05D 23/00	F	8835-5H			
H01L 21/027					
21/205		7739-5F			
21/31	B	6940-5F			
21/324	Z	7738-5F			
H05B 3/00	310 C	7719-3K			
		2104-5F	H01L 21/30	361	H

(43) DATE OF PUBLICATION
27. 08. 1991

Request for Examination: Not Filed Number of Claims: 1 (6 pages total)

(54) Title of the Invention HEAT TREATMENT DEVICE
(21) Japanese Patent Application No. H1-335774
(22) Filing Date: 25. 12. 1989(H1)
(72) Inventor: Kimiharu MATSUMURA c/o TEL Kyushu KK, 2655 Tsukure, Kikuyoumachi, Kikuchi-gun, Kumamoto
(72) Inventor: Hidekazu SHIRAKAWA c/o TEL Kyushu KK, 2655 Tsukure, Kikuyoumachi, Kikuchi-gun, Kumamoto
(71) Applicant: Tokyo Electron LTD 1-26-2 Nishishinjuku, Shinjuku-ku, Tokyo
(71) Applicant: Tokyo Erekutoron Kyushu KK, 2655 Tsukure, Kikuyoumachi, Kikuchi-gun, Kumamoto
(74) Representative: Patent Attorney Masami SATO

Description

1. Title of the Invention

Heat Treatment Device

2. Claim(s)

A heat treatment device for heating a subject to be treated by a heating means and thus performing a predetermined treatment thereon, characterized in that

a heat flux detection means is provided for detecting a heat flux imparted from the heating means to the subject, and

the heating means is controlled based on an output of the heat flux detection means.

3. Detailed Description of the Invention

[Industrial Applicability]

[0001] The present invention relates to a heat treatment device.

[Description of the Prior Art]

[0002] In processes of manufacturing a semiconductor integrated circuit, various heat treatment processes are employed; e.g., baking, depositing and ashing in a photolithography process.

[0003]Conventionally, the heat treatment, e.g. the baking is performed in such a manner that for example, in a case of single wafer processing, a substrate to be treated is mounted on a heating plate made of, for example, SUS or aluminum and having a heating resistor such as a nichrome wire built therein, a temperature sensor such as a thermocouple or a thermometric resistor is embedded, for example, in the heating plate, and then a temperature is monitored by the temperature sensor, thereby controlling a treatment temperature.

[Problem to be solved by the Invention]

[0004] As described above, a temperature control technique in the conventional heat treatment device is a type, in which a temperature is monitored for temperature control, and thus causes a delay in control. Accordingly, when a temperature of a subject to be treated is increased to a predetermined temperature or decreased to a predetermined temperature, or when a change in temperature is likely to be caused due to an influence of a disturbance and the like, a precise control with a good responsiveness is difficult.

[0005] Specifically, the heating plate and thus the substrate to be treated are heated by a heat flux generated from a heating body such as a heater (heat flux is calorie per unit area and unit time; the unit is kcal/m^2·h), and in general, a temperature is an integral value of a heat flux with respect to time and coordinate (the following thermal diffusion equation (1) and Fourier's law equation (2)). Accordingly, when a heat flux is determined, temperatures of the heating plate and the subject to be treated are determined as a result thereof. Thus, a predetermined correlation exists between the heat flux and the temperature (the following thermal diffusion equation (3))

$$\frac{\partial T}{\partial t} = \frac{k}{\rho C_p} \cdot \frac{\partial^2 T}{\partial y^2} \qquad \cdots(1)$$

$$q = k\frac{\partial T}{\partial y} \qquad \cdots(2)$$

$$\frac{\partial T}{\partial t} = \frac{1}{\rho C_p} \cdot \frac{\partial q}{\partial y} \qquad \cdots(3)$$

where T: temperature, q: heat flux, t: time, y: coordinate, ρ: density, Cp: thermal capacity and k: thermal conductivity.

[0006] Accordingly, as a change in phenomenon, a heat flux tend to be detected earlier than a temperature, and thus a delay in control is occurred when the temperature is monitored. Therefore, in the conventional temperature control technique using the temperature monitoring, when a change in temperature is likely to be caused due to a disturbance and the like, it is impossible to predict a change in temperature caused by the disturbance based on the state of a set temperature and to perform control so as to suppress the disturbance.

[0007] Also, when attempting to control a temperature history during increasing or decreasing the temperature to a predetermined temperature, it is impossible to predict and control a temperature in accordance with a predetermined temperature history. In addition, even if a disturbance is occurred during increasing and decreasing of the temperature and thus a heat flux is varied from an initial value thereof, a timing at which an action can be taken with respect thereto in the temperature monitoring type is after a change in temperature is exhibited, and thus a delay in control is inevitable. Therefore, in the conventional temperature control technique, it is difficult to precisely and accurately obtain a desired temperature change pattern during increasing or decreasing of the temperature.

[0008] Further, a baking process is a heat treatment for removing a solvent in a photoresist after application of the photoresist, exposure of the photoresist film, development thereof and the like and also controlling physical properties (photosensitivity, resolution and the like) of the resist while imparting a thermal resistance to the resist, and is intended to heat a semiconductor wafer or the like at a predetermined desired temperature during a predetermined period of time, for example, as disclosed in Japanese Patent Application Publication No. S61-201426.

[0009] For example, as shown in Fig. 2, a substrate to be treated is set to a predetermined temperature T_1 by a heating plate and then is heated during a predetermined set time D_2 in a state where the temperature T_1 is kept.

[0010] However, in Fig. 2, the related art performs a temperature management in such a manner that during a period of the set temperature T_1, the temperature is kept constant, but does not manage a history (temperature change pattern) at all such as temperature change gradients during a temperature increasing period D_1 and a cooling period D_3 and time lengths thereof.

[0011] As such, because a temperature change pattern during increasing or decreasing of the temperature is not managed, even if substrates to be treated are semiconductor wafers of the same type, the pattern of each substrate is different from each other and thus physical properties of the resist in each substrate is also different from each other, thereby causing a problem in that reliability lacks.

[0012] In addition, recently, a resist pattern becomes finer as a density and a degree of integration of a semiconductor device increase. Therefore, physical properties of the photoresist, such as resolution or photosensitivity are gradually non-negligibly influenced by a temperature change pattern during a temperature increasing period or a temperature decreasing period, which has been conventionally ignored in the baking process. Accordingly, it is necessary to control a history, such as temperature change patterns during increasing or decreasing of the temperature, so that the history takes a predetermined pattern and thus to obtain better resist physical properties.

[0013] Thus, it may be considered to perform temperature control even during the temperature increasing period and the temperature decreasing period; but as described above, because the conventional temperature control technique is a type in which a temperature is controlled by monitoring the temperature, a delay in control is occurred, in particular in a case where a sharp temperature change occurs. Thus, it is impossible to predict a temperature change and to control a temperature history so that the history follows a desired pattern.

[0014] In view of the above, an object of the present invention is to provide an improved heat treatment device addressing the above problems by allowing a prediction and contol of the temperature change.

[Means for Solving Problem]

[0015]According to the present invention, there is provided a heat treatment device for heating a subject to be treated by a heating means and thus performing a predetermined treatment thereon,

characterized in that wherein a heat flux detection means is provided for detecting a heat flux imparted from the heating means to the subject, and

the heat treatment device is configured to control the heating means based on an output of the heat flux detection means.

[Function]

[0016] As described above, as a phenomenon, the change in a heat flux may respond more quickly than that in temperature. In addition, due to a predetermined correlation between the heat flux and the temperature, a change in temperature can be predicted by monitoring the heat flux (the foregoing equation (3)). Accordingly, even in a situation where a disturbance exists, the temperature can always be stably controlled and a desired temperature increasing or decreasing characteristics can be precisely managed.

[Embodiments]

[0017]Now, one embodiment of a heat treatment device according to the present invention, which is applied to a baking apparatus that performs a photolithograph process, will be described by way of example with reference to the accompanying drawings.

[0018]In Fig. 1, a hot plate 1 is made of a metal and has a heating resistor 2 embedded therein. A semiconductor wafer 3 is mounted on the hot plate 1 and controllably heated by the hot plate 1 as described below.

[0019] The heating resistor 2 of the heating plate 1 is supplied with an electric power, for example, from a commercial alternating current power source 4 via a switching element, in this example via SSR (Solid State Relay) 5. In this case, the SSR 5 is controllably switched by a PWM (pulse width modulation) signal SM from a temperature control circuit 10 having a computer as described above, and thus an alternating current is allowed to flow through the heating resistor 2 during a period of time corresponding to a pulse width of the signal SM, so that the heating resistor 2 generates heat corresponding to an amount of supplied electric power. Therefore, by changing a pulse width of the PWM signal SM, an amount of electric power per one cycle T of the signal SM to be supplied to the heating resistor 2 can be adjusted and thus a temperature of the hot plate 1 can be controlled. Namely, in this case, a temperature of the hot plate 1 corresponds to the average of a temperature achieved by microscopic rise caused by the supply of an electric power to the heating resistor 2 during a period of time of a pulse width W of the PWM signal SM, and a temperature achieved by microscopic decrease caused by the interruption of the electric power to the heating resistor 2 during a period of time after the period of time of the pulse width.

[0020] Thus, assuming that temperature increasing and decreasing characteristics of the hot plate 1 are the same, the temperature of the hot plate 1 does not change, for example, when the pulse width W of one cycle T of the PWM signal SM is 1/2T, namely, when a duty ratio thereof is 50%. When the pulse width W of the PWM signal SM is wider than 1/2T, the temperature of the hot plate 1 rises with a gradient corresponding to the pulse width W, whereas when the pulse width W of the PWM signal SM is narrower than 1/2T, the temperature of the hot plate 1 lowers with a gradient corresponding to the pulse width W. In this way, by changing the pulse width W of the PWM signal SM, the temperature of the hot plate 1 can be freely controlled.

[0021] A temperature sensor 6 including, for example, a thermocouple or a thermometric resistor is provided in the vicinity of a surface of the hot plate 1, where the wafer 3 is to be mounted, and an output of the temperature sensor 6 is supplied to a thermometer 7. Then, an output signal of the thermometer 7 corresponding to a detected temperature is supplied to the temperature control circuit 10.

[0022] A heat flux sensor 8 is provided in the vicinity of a surface of the wafer 3 and an output of the heat flux sensor 8 is supplied to a heat flux meter 9, whereby a heat flux q is obtained. Then, the heat flux q is supplied to the temperature control circuit 10. The heat flux sensor 8 is configured with a thin plate material (thickness d) having a thermal conductivity λ small enough to detect a very small temperature error, and a heat flux q flowing through the thin plate can be obtained by the following equation.

$$q = \frac{\lambda}{d} \cdot \Delta T \qquad \ldots(4)$$

[0023]Because ΔT is a difference in temperature between both front and back surfaces of the thin plate and λ and d are known, a heat flux q can be obtained through the heat flux meter 9 by measuring ΔT, for example, using a differential thermocouple provided in the heat flux sensor 8. The temperature control circuit 10 predicts a change in temperature of the wafer 3 from the heat flux q (based on the principle of the above equation (3)).

[0024] In addition, the hot plate 1 has a pin, not shown, inserted therethrough for lifting a semiconductor wafer 3 from the hot plate 1 while supporting the wafer 3. The semiconductor wafer 3 is transported onto the hot plate 1 by a transport mechanism, not shown, and is loaded onto or unloaded from the hot plate 1 by the lifting or lowering of the pin.

[0025] Next, a baking process using the heat treatment device configured as in Fig. 1 will be described.

[0026] First, the pin, not shown, as described above is lifted from a surface of the hot plate 1. Then, a transported semiconductor wafer 3 is mounted onto the lifted pin. Subsequently, the pin is lowered so that the semiconductor wafer 3 is mounted and then held on the hot plate 1 by adsorption. Then, the semiconductor wafer 3 is heated by heat conduction from the hot plate 1 in accordance with a temperature control as follows.

[0027] In the case described here, as described above, the temperature control circuit 10 has a computer, and thus a specification (recipe) intended to exhibit a suitable temperature history depending on types of subjects such as the semiconductor wafer 3 is inputted and stored by a baking pattern input means 11 such as a keyboard. A temperature control is performed in accordance with the recipe.

[0028] Fig. 3 shows, as an example of the recipe, a heat history, in which a temperature rises from a room temperature of 20℃ to 120℃ with a predetermined gradient over 60 seconds, and then the temperature of 120℃ is kept for 60 seconds before decreasing to the room temperature of 20℃ over 60 seconds. In order to reproduce this heat history, for example, points P0 to P8 as in Fig. 3 are defined and then time and temperature information at each of the points P0 to P8 is inputted, thereby the recipe is input.

[0029] The temperature control circuit 10 calculates a temperature gradient between two adjacent points (e.g., P1-P0) during a temperature increasing period of points P0 to P3 and a temperature decreasing period of points P5 to P8, based on information of the two points, and then supplies a PWM signal SM, which has a pulse width W corresponding to the temperature gradient, to the SSR 5. Then, at this time, the heat flux meter 9 detects a heat flux from the hot plate 1, based on an output signal proportional to a temperature difference detected by the heat flux sensor 8, and thus the pulse width W of the signal SM is controlled to gradually correct an error between a temperature calculated from the recipe and a temperature of the wafer 3 estimated from the heat flux while referring to a correlation, as previously obtained, between the heat flux and a change in the temperature of the wafer (the following equation (5)).

$$(\text{Change in Temperature of Wafer}) = \frac{\partial T_s}{\partial t} = \frac{1}{\rho C_p} \cdot \left(\frac{\partial q}{\partial y}\right)_s \qquad \cdots(5)$$

where

$$\left(\frac{\partial q}{\partial y}\right)_s = \frac{1}{\rho C_p} \cdot \frac{q - q_s}{L} = \frac{q}{\rho C_p} \cdot f(L, t, q_s)$$

where T: temperature, t: time, q: heat flux, y; coordinate
L: a distance between the wafer and the heat flux sensor
ρ: density of air, Cp: thermal capacity of air
: body of the heat flux sensor, s: wafer surface
f(L, t): a function representing a predetermined relationship between q and qs.

[0030] In addition, during the temperature increasing period P0 to P3 and the temperature decreasing period P5 to P8, verification of results of temperature control is performed by additionally referring to temperature information from the temperature sensor 6.

[0031] In a period between points P3 to P5, during which a temperature is settled, the temperature control circuit 10 controls the heating resistor 2 by referring to only temperature information measured from the temperature sensor 6. This is because the hot plate 1 has a relatively large thermal capacity and thus is hardly influenced by a disturbance after the temperature has been settled. Basically, in a state where the hot plate 1 is being influenced by a disturbance, it is preferable to control the heat resistor 2 by additionally referring to the heat flux from the heat flux meter 9.

[0032] Meanwhile, in this case, for example, a liner control technique such as a PID control technique can be employed as a temperature control technique. Namely, a temperature (reference temperature) at every moment is obtained, for example, based on a gradient calculated from information of two points during the temperature increasing period, and then an error between the reference temperature and a temperature of the wafer 3 estimated from the heat flux detected by the heat flux meter 9 is obtained. Then, an amount of electric power to be supplied is calculated from the temperature error, and correspondingly, a pulse width W of the PWM signal SM is adjusted.

DOCKET ALARM

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.

WHAT WILL YOU BUILD? | **sales@docketalarm.com** | **1-866-77-FASTCASE**

fastcase®
Smarter legal research.