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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

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(54) Title of the Invention　SEMICONDUCTOR MANUFACTURING DEVICE

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Description

1. Title of the Invention

Semiconductor Manufacturing Device

2. Claim(s)

(1) A semiconductor manufacturing device, which heats or cools a substrate placed inside a vessel to maintain the temperature of the substrate at a specified temperature, and in this condition performs a specified process on the substrate, characterized in that the semiconductor manufacturing device comprises:

a first temperature control mechanism provided in contact with the rear surface of the substrate and heats or cools the substrate by at least thermal conduction, and

a second temperature control mechanism that heats the substrate by radiant heat from the front surface side of the substrate.

(2) A semiconductor manufacturing device according to claim 1, characterized in that the first temperature control mechanism is a heater that is heated by electric conduction or a heat exchanger that is heated or cooled by heat exchange with a fluid, and the second temperature control mechanism is an infrared lamp.

3. Detailed Description of the Invention

[Purpose of the invention]

(Industrial Applicability)

[0001] The present invention relates to a semiconductor manufacturing device that is used for forming a thin film, etching, or the like, and in particular relates to a semiconductor manufacturing device which has a function for controlling the temperature of a substrate by heating and cooling the substrate.

(Description of the Prior Art)

[0002] With the shift to a higher integration of the semiconductor devices, regarding thin film forming technology and etching technology which are used in the manufacturing of the same, there is an emerging need to accurately control the reactions on the substrate. Further, the substrate diameter is increasing and due to this, there is a shift from semiconductor manufacturing devices performing batch processing, which processes multiple sheets of substrates at once, to semiconductor manufacturing devices using batch processing that processes a smaller number of substrates at once, and even to semiconductor manufacturing devices performing single substrate processing.

[0003] In this way, due to the decrease in the number of substrates that can be processed in one operation, the problem of a decreased throughput (the number of substrates per unit time on which thin films are formed) arises.

For example, with the decrease of the number of substrates that can be processed in one thin film forming operation, more time is required for the thin film forming operation per substrate, and the throughput decreases. One reason for the throughput decrease is the increased time required for heating and stabilizing the temperature of the substrate. In the batch processing, one heating and temperature stabilization operation was sufficient for dozens of substrates, while in the single substrate processing, this operation is done for each substrate.

[0004] For example, when forming a tungsten film on the substrate using the tungsten selective CVD, a cold-wall type device performing a single substrate processing is generally used, in which a raw material gas is fed into the chamber equipped with a heating mechanism for heating a single substrate. In this case, as means for heating the substrate, a hot plate as shown in Fig.5 (a) which mainly uses heat conduction is employed to heat the substrate from its rear surface side, or an infrared lamp as shown in Fig.5 (b) is used which heats the substrate from its front surface side using radiant heat. In Fig. 5, 1 is the substrate, 2 is the hot plate, 3 is the infrared lamp, 4 is a stage, 5 is a transparent window, and 6 is a reflector.

[0005] Film forming is performed at substrate temperature of 200-400°C. When the hot plate is used for heating, the substrate temperature can be accurately controlled within the temperature range of room temperature to 300°C. However, as a hot plate generally has a large heat capacity it requires more time for the temperature to rise and fall, and its disadvantage is that it is difficult to stabilize the substrate temperature in a short time by changing its output. Furthermore, it is also difficult to effectively achieve a high substrate temperature of 400°C or more. On the other hand, when the infrared lamp is employed, it is possible to rapidly raise the substrate temperature, but it is difficult to control the substrate temperature within a temperature range below 400°C, and the disadvantage is that it takes time to stabilize the substrate temperature.

[0006] Thus, with the semiconductor manufacturing device which performs single substrate processing, if only one method is employed for heating the substrate, it takes time to raise or stabilize the substrate temperature and causes a further decreased throughput.

[0007] On the other hand, when etching is performed, since there is now a need to more accurately control the etched shape, substrate temperature is controlled to or below room temperature. For example, by using CFC (chlorofluorocarbons) gas or the like, temperature is controlled at around minus several tens degrees (°C). However, while it is easy to control the temperature so that the substrate is sufficiently below the room temperature, it is difficult to control the temperature so that the substrate is at around the room temperature to increase the etching speed.

(Problem to be solved by the invention)

[0008] Thus, conventionally, when the substrate is heated from one side by a single heating method, there are problems that it took time to increase or stabilize the temperature of the substrate, the processing time required for one substrate increased, and the throughput decreased. Furthermore, it was extremely difficult to control the temperature to maintain the substrate temperature at around the room temperature.

[0009] The present invention is made in consideration of the above, and an object of the present invention is to provide a semiconductor manufacturing device that can quickly increase and stabilize the substrate temperature and can contribute, for example, to increase the throughput.

[Configuration of the Invention]

(Means for solving problem)

[0010] The gist of the present invention lies in that multiple heating methods, not a single heating method, are employed to rapidly increase and stabilize the substrate temperature.

[0011] Therefore, the present invention relates to a semiconductor manufacturing device, which heats or cools a substrate placed inside a vessel to maintain the temperature of the substrate at a specified temperature, and in this condition performs a specified process on the substrate, characterized in that the semiconductor manufacturing device comprises:

a first temperature control mechanism provided in contact with the rear surface of the substrate and heats or cools the substrate by at least thermal conduction (for example, a heater that is heated by electric conduction or a heat exchanger that is heated or cooled by heat exchange with a fluid), and a second temperature control mechanism that heats the substrate by radiant heat from the front surface side of the substrate (for example, an infrared lamp).

(Function)

[0012] According to the present invention, by using a heater or a heat exchanger or the like as the first temperature control mechanism, the substrate can be heated or cooled by thermal conduction and good substrate temperature control characteristics can be achieved at the room temperature to 300°C.

Further, by using an infrared lamp or the like as the second temperature control mechanism, while the substrate temperature control characteristic at a low temperature is poorer, the substrate can be heated rapidly. Additionally, by using the first and second temperature control mechanisms in combination, it is possible to increase and stabilize the substrate temperature in short time.

[0013] While a heater and a heat exchanger using thermal conduction generally have a large heat capacity and temperature stabilization is easy, rapid heating and cooling is difficult. It is particularly difficult to heat to a high temperature. On the contrary, an infrared lamp that uses radiant heat generally has a small heat capacity and while rapid heating and cooling is easy, it is difficult to stabilize the temperature. It is particularly difficult to stabilize at a low temperature. In the present invention, by using two types of heating means together, for example, by rapidly increasing the temperature using the infrared lamp and stabilizing the temperature after heating using a heater or heat exchanger, it is possible to heat the substrate in a short amount of time to a specified temperature and to stabilize at this temperature.

(Embodiments)

[0014] The examples of the present invention will be described with reference to the figures.

[0015] Fig. 1 is a sectional view illustrating a schematic structure of a semiconductor manufacturing device according to a first embodiment of the present invention. In the first embodiment, th semiconductor manufacturing device is a thin film forming device. In the drawing, 10 is a vacuum vessel, and a specified gas is fed into the vessel 10 from a gas introduction port, and a gas inside the vessel 10 is exhausted from an exhaust port. The first temperature control mechanism 30, serving also as the stage where the substrate 20 such as an Si wafer is mounted, is provided on the bottom part of the vessel 10, and the second temperature control mechanism 40 is provided on the upper part of the vessel 10.

[0016] The first temperature control mechanism 30 includes a heater 31 having an electrode 32 equipped on the upper part as an electrostatic chuck, and heats the substrate 20 from the rear surface side with the thermal conduction. The second temperature control mechanism 40 includes an infrared lamp 41, a quartz window 42 and a reflector 43, and heats the substrate 20 from the front surface side with radiant heat.

Furthermore, a thermocouple 33, which measures the temperature of the substrate 20, is provided inside the temperature control mechanism 30. According to the temperature detected by the thermocouple 33, the output of the heater 31 and the infrared lamp 41 is controlled. It is desirable that the thermocouple 33 is in direct contact with the substrate 20, but it is acceptable if it is provided near either the heater 31 or the infrared lamp 41 or both, can calibrate with the substrate temperature, and can control the output of either the heater 31 or the infrared lamp 41.

[0017] Next, a thin film forming method using the above device will be described. Here, for the heater 31 of the first temperature control mechanism 30, a hot plate (maximum output 1kW) including a tungsten wire enclosed inside an alumina ceramic and sintered is used, and for the infrared lamp 41 of the second temperature control mechanism 40, a 600W halogen lamp is used. As for the gas fed into the vessel 10, WF_6, SiH_4 and H_2 are used.

[0018] First, while the air is exhausted from the vessel 10 to make the internal pressure 1mTorr or less, the substrate 20 is carried onto the hot plate 31 whose output is maintained at a constant level. Thereafter, the halogen lamp 41 is lit and more heat energy is provided to the substrate 20 to rapidly increase the temperature of the substrate 20. When the substrate 20 approaches the specified temperature, the output of the halogen lamp 41 is decreased, and the substrate 20 is heated mainly with the hot plate 31. Then in this condition, gas is fed to the vessel 10, and a thin tungsten film is deposited by tungsten selective CVD.

[0019] Fig. 2 (a) shows the relation of the hot plate, halogen lamp output, and the substrate temperature. The hot plate 31 is controlled to a constant output of 300W wherein the substrate temperature rises to 300°C when heated by the hot plate 31 alone. When the substrate 20 of the room temperature is carried in, the output of the halogen lamp is simultaneously set to the maximum of 600W and the halogen lamp heats the substrate 20 together with the hot plate 31. When the substrate temperature reaches 290°C, the output of the halogen lamp is decreased and eventually made zero.

[0020] In this case, the substrate temperature is stabilized at 300°C in 2 minutes. In comparison, with the hot plate alone with a constant output of 300W, it required 15 minutes before the temperature is stabilized at 300°C, and with the halogen lamp alone it required 5 minutes before the temperature is stabilized at 300°C. In this way, according to the embodiment, it is possible to increase the substrate temperature in a short time. In the above, the substrate temperature is measured by a thermocouple (not shown in figure) fixed on the substrate surface separate from the thermocouple 33 for temperature control, and the following substrate temperatures were measured in the same way.

[0021] According to the embodiment, by using the hot plate 31 to heat the substrate 20 by thermal conduction from the rear surface side, and by using halogen lamp 41 to heat the substrate 20 by radiation from the front surface side, the substrate 20 can be heated to a specified temperature in a short time, and the substrate can also be held stable at that temperature. Therefore, the time required to process the substrate 20 in thin film forming can be shortened and the throughput can be increased. This is a significant effect on a single substrate processing device.

[0022] Furthermore, in the embodiment, in addition to the throughput increase due to the shortened heating and temperature stability time, since the quartz window 42 is not heated while the tungsten is deposited, tungsten adhesion on the quartz window 42 rarely occurred, which further provides an effect of controlling debris production. In addition, after the tungsten deposition, if heating process at or above deposit temperature is continuously performed in order to increase adhesion, heating by the halogen lamp 41 and the hot plate 31 can be performed simultaneously after the tungsten deposition as shown in Fig. 2(b). Further, if the electrostatic chuck 32 is not used, the effect of the thermal conduction decreases. Hence, it was necessary to increase the output of the hot plate by 50% for the substrate temperature (to be) 300°C. In short, the heating effect was increased by using the electrostatic chuck 32.

[0023] With respect to the hot plate 31, as long as the face of the jig where the substrate is placed is heated, the jig may be heated with a heating element using Joule heat, such as silicon carbide and graphite, or may be heated by infrared lamp, such as halogen, that uses radiation.

The reason the output of the hot plate 31 is kept constant is because its heat capacity is large and it is difficult to change the temperature in a short amount of time. However, the output of the hot plate 31 can be changed if there is a waiting period such as during the substrate carry or gas exhaustion, and if it is at the range wherein the hot plate 31 surface temperature will revert back to the specified temperature by forced cooling.

[0024] Fig. 3 is a sectional view illustrating a schematic structure of a semiconductor manufacturing device according to another embodiment of the present invention; in this embodiment, an etching device is described. It should be noted that parts that are the same as Fig. 1 are denoted by the same symbols and detailed descriptions thereof will be omitted.

[0025] In this embodiment, a heat exchanger 34 is used instead of the hot plate 31 as the first temperature control mechanism 30, and halogen lamp 41 is used as the second temperature control mechanism 40 as in the previous embodiment. The following is an example of maintaining the substrate temperature at around the room temperature by performing substrate cooling by the heat exchanger 34 and heating by the halogen lamp 41 at the same time. Additionally, in this embodiment, RIE was performed by magnetron electric discharge, but the magnet and the electrode for the magnetron electric discharge are not shown in the drawing.

[0026] First, 5°C cooling water with a flow rate of 1L/minute is fed into the heat exchanger 34 and the substrate 20 is cooled. At the same time, the output of the halogen lamp 41 is changed to 0-400W and the substrate 20 is heated. With this, in the range of substrate temperature of 15 to 150°C, the substrate temperature was controlled to the specified temperature within 3 minutes. By forcefully performing cooling and heating and increasing the heat transfer amount, the substrate temperature was controlled rapidly even at around the room temperature. In contrast, when heating is performed only by a heat exchanger or a halogen lamp and the temperature is controlled at around the room temperature, if the substrate is overheated, the temperature difference with its surroundings is small and the heat transfer amount is small, so it is difficult to lower the temperature. Furthermore, in order not to overheat, it is necessary to heat while accurately controlling the temperature, and it took more than ten minutes for temperature control.

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