US 20010007246A1

(19) United States

(12) Patent Application Publication (10) Pub. No.: US 2001/0007246 A1

Ueda et al. (43) Pub. Date: Jul. 12, 2001

(54) THIN-FILM DEPOSITION APPARATUS

(76) Inventors: **Masashi Ueda**, Tokyo (JP); **Tomoko Takagi**, Tokyo (JP)

Correspondence Address:
KANESAKA AND TAKEUCHI
727 Twenty-Third Street South
Arlington, VA 22202 (US)

(21) Appl. No.: 09/749,681

(22) Filed: Dec. 28, 2000

(30) Foreign Application Priority Data

Dec. 28, 1999 (JP) 11-374422

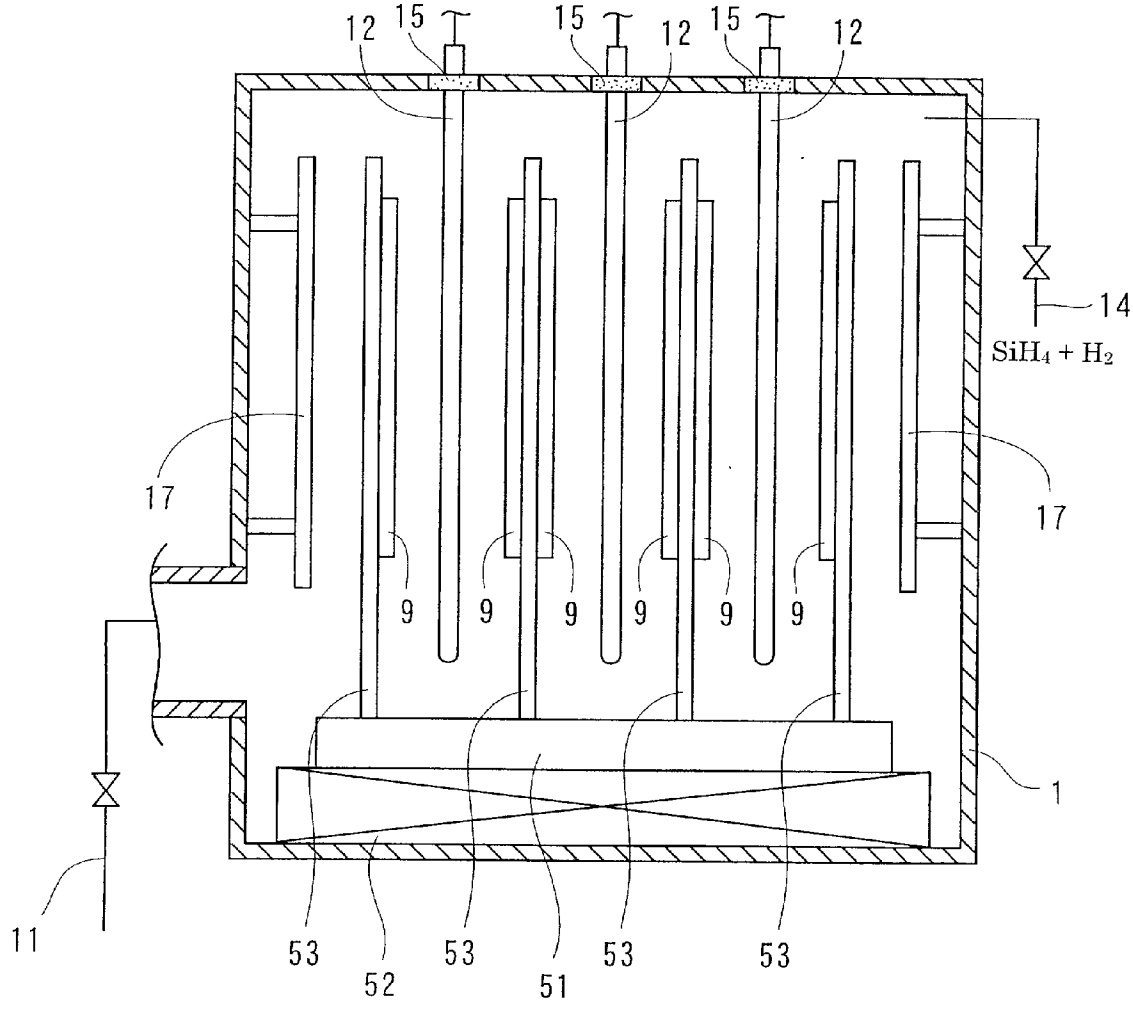
Publication Classification

(51) Int. Cl.[7] C23C 16/00

(52) U.S. Cl. 118/724

(57) ABSTRACT

Object of the invention is to present a thin-film deposition apparatus comprising a practical means of heating not by the radiation heating, which is suitable for manufacture of solar cells. To accomplish this object, a thin-film deposition apparatus of the invention comprises a deposition chamber which is a vacuum chamber where thin-film deposition is carried out on a substrate at a deposition temperature higher than room temperature, a load lock chamber which is a vacuum chamber where the substrate stays temporarily while it is transferred from an atmosphere to the deposition chamber, and a heat chamber which heats the substrate under atmospheric pressure or a pressure higher than the atmospheric pressure. The heat chamber, the load lock chamber and the deposition chamber are connected directly or indirectly in this order interposing a valve. The heat chamber has a mechanism to heat the substrate supplying gas of a temperature higher than the room temperature by forced convection. The heating mechanism heats the substrate at a temperature higher than the deposition temperature. A temperature-decrease prevention mechanism which prevents the substrate temperature from decreasing lower than the deposition temperature is provided in the load lock chamber.



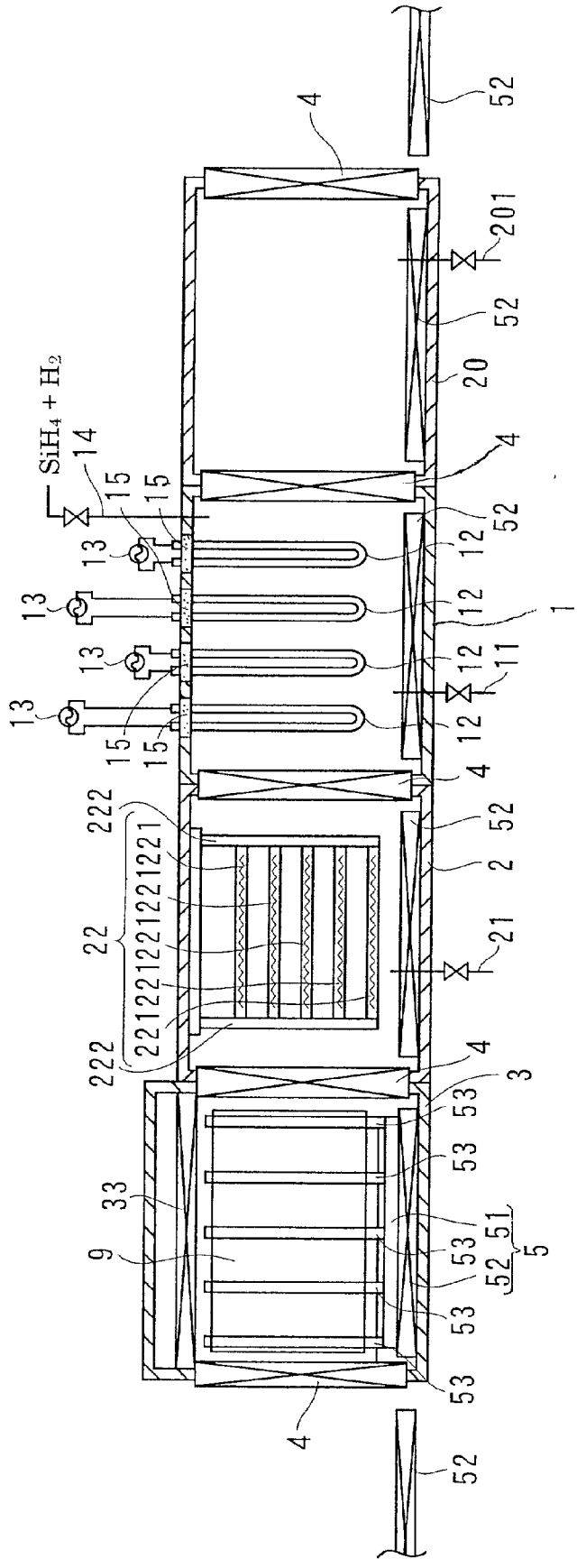

$SiH_4 + H_2$
14
15
15
13
13
13
13
15
15
4
52
201
52
20
4
52
12
12
12
12
1
11
4
52
2
21
4
3
53
53
53
53
53
53
33
9
51
52
5
4
52

Fig. 1

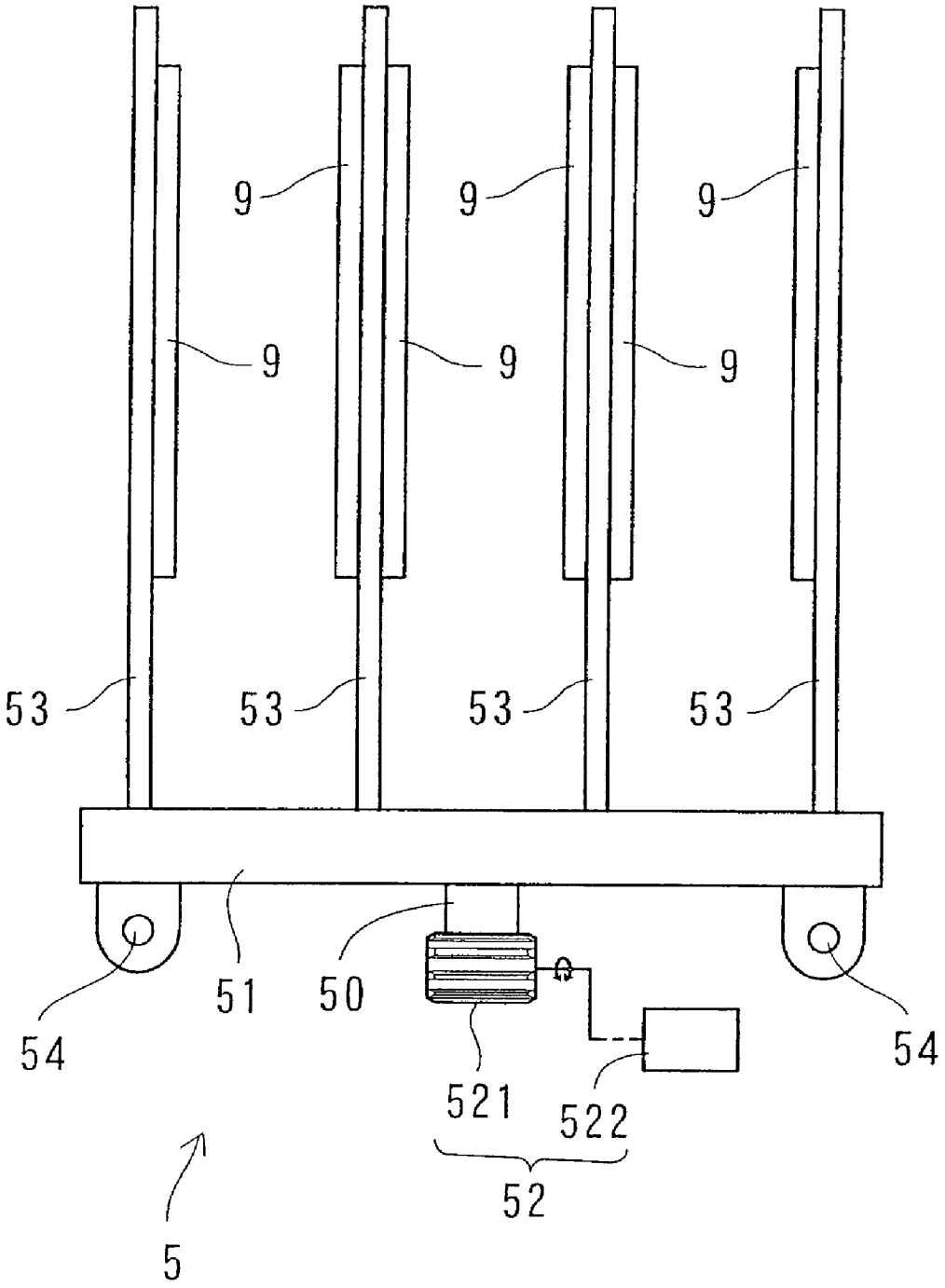


Fig. 2

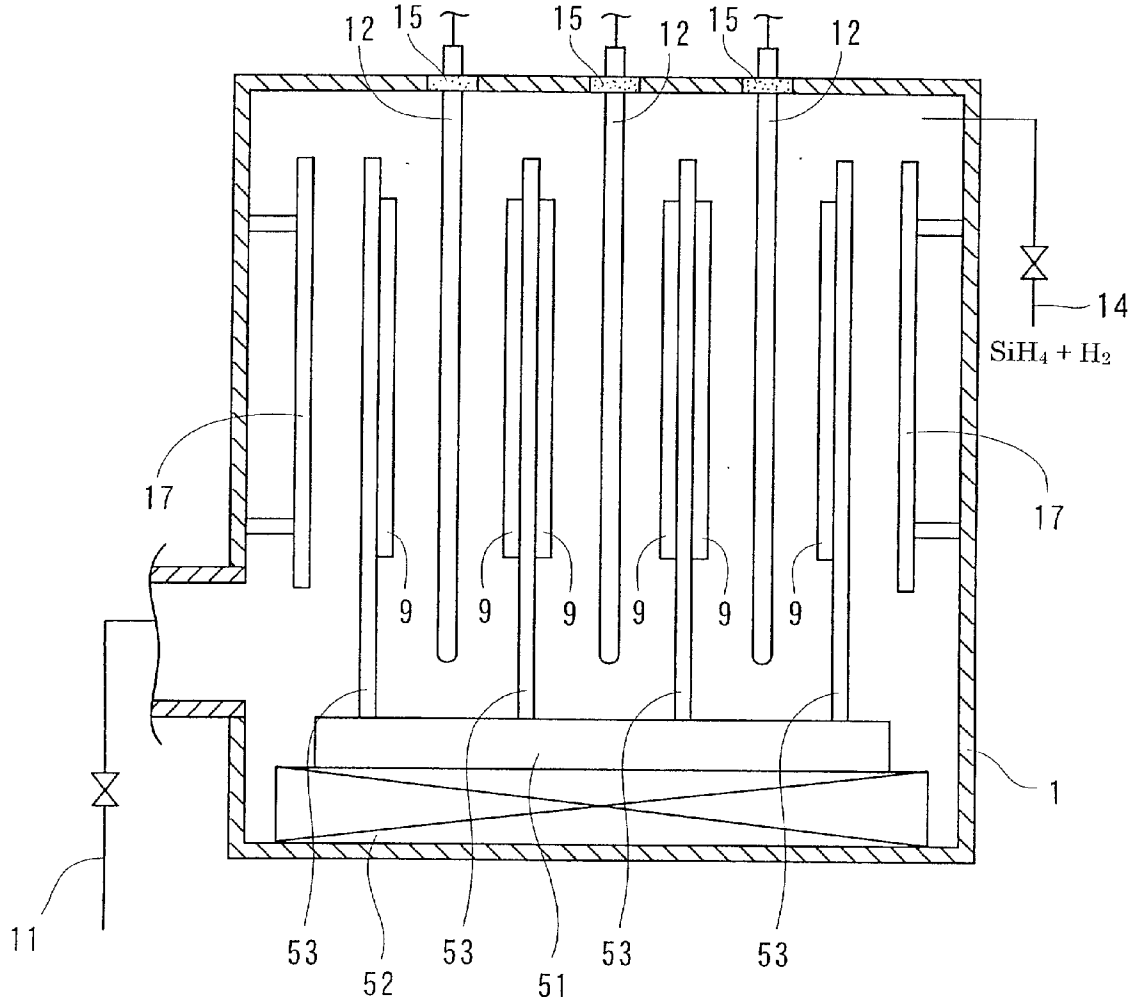


Fig. 3

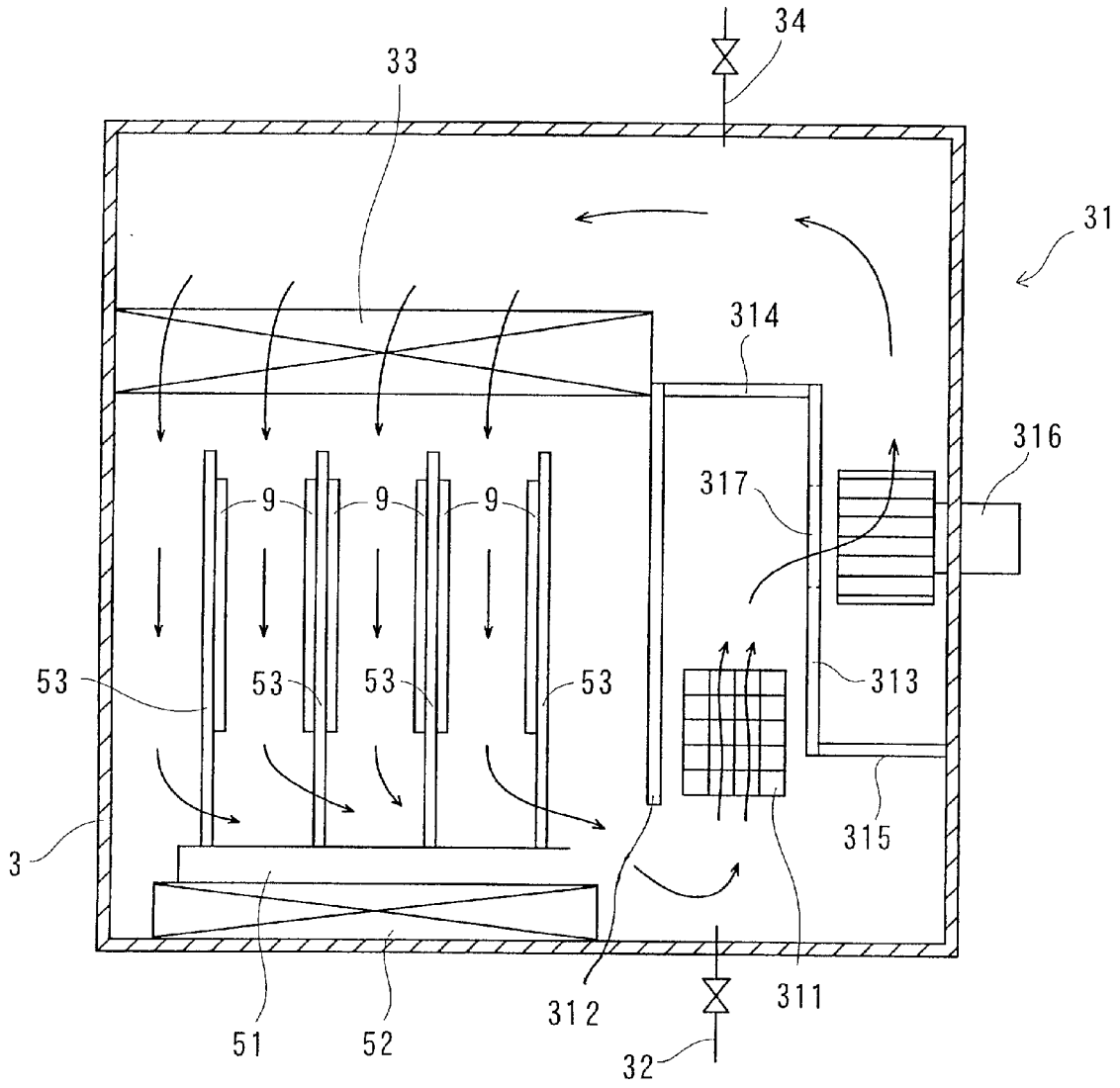


Fig. 4

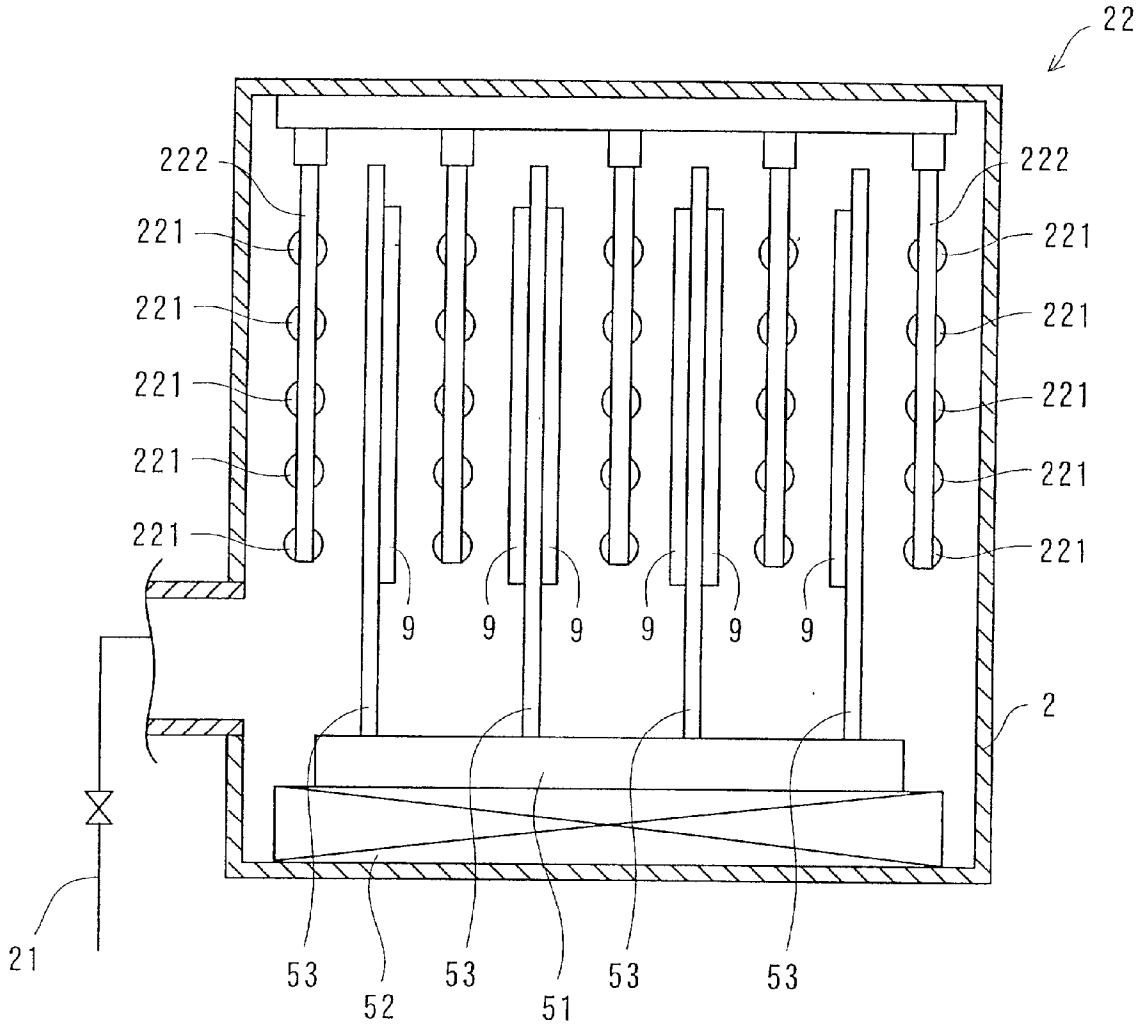

22
222
221
221
221
221
221
222
221
221
221
221
221
9
9
9
9
9
9
2
21
53
52
53
51
53
53

Fig. 5

THIN-FILM DEPOSITION APPARATUS

BACKGROUND OF THE INVENTION

[0001] The invention of this application relates to a thin-film deposition apparatus suitably used for manufacture of solar cells. Thin-film deposition apparatuses, which deposit a thin-film on a substrate, are widely used for manufacture of electronic devices such as LSIs (large-scale integrated circuits) and display devices such as liquid crystal displays. In addition, thin-film deposition apparatuses may be used for manufacture of solar cells.

[0002] Though solar cell technology has been made into practical use in electronic calculators conventionally, now it is expected very much as electric power generating technology under increase of energy problems, as observed in the New Sunshine Program of the MITI (Ministry of International Trade and Industry).

[0003] Solar cells are divided into two kinds. One is silicon solar cell. The other one is compound semiconductor solar cell. Though the silicon solar cell includes crystallized solar cells such as single crystalline silicon solar cells and poly-crystalline silicon solar sells, much effort has been done to make amorphous silicon solar cell practical. This is because the semiconductor layers in the amorphous silicon solar cell could be thinner because of its higher light absorption coefficient, as well as its lower manufacturing cost. In addition, the amorphous solar cell has no worry of resource exhaustion since it utilizes gas sources, contrarily the crystal silicon that is the resource of the crystal silicon solar cell is limited since it is raw material.

[0004] In manufacture of the amorphous solar cell, it is necessary to deposit a thin-film on a substrate made of glass, metals or resin. Therefore, a thin-film deposition apparatus is used. In manufacture of an amorphous silicon solar cell that is the typical amorphous solar cell, technique of plasma enhanced chemical vapor deposition (CVD) using gas mixture of silane and hydrogen is often adopted. For example, a hydrogenated amorphous silicon film is deposited on a substrate, by generating a HF discharge of the gas mixture of silane and hydrogen and utilizing decomposition of silane thereby.

[0005] In thin-film deposition apparatuses, temperature of a substrate that is maintained at a specified value during deposition, hereinafter called "deposition temperature", is often higher than room temperature. In CVD, the deposition temperature is set higher than the room temperature on purpose that the final reaction could take place by thermal energy, or, the deposition rate and the film quality could be enhanced. Therefore, process of heating the substrate prior to the deposition is required.

[0006] A heat chamber in which radiation lamp-heaters are provided is usually used for heating the substrate. The heat chamber is connected airtightly with a deposition chamber interposing a valve. The substrate is heated in the heat chamber up to the deposition temperature in vacuum, and is transferred to the deposition chamber for the film deposition. The reason why the radiation heating is employed is that internal environment of the apparatus is often a vacuum pressure of about 10 Pa or lower, where heat transfer by conduction and convection cannot be expected.

[0007] A load lock chamber is often connected with the deposition chamber so that the deposition chamber may not be opened directly to the atmosphere. The load loch chamber is sometimes commonly used as the heating chamber by providing radiation lamp-heaters in it.

[0008] However, the above-described radiation heating has problems as follows.

[0009] First of all, the radiation heating has a problem that the running cost is high because heating efficiency of the radiation heating is worse than other heating methods. In addition, when a larger substrate is employed, which often happens in the solar cell manufacture, increase of the apparatus cost becomes remarkable because many longer radiation lamp-heaters must be provided. Moreover, it is required to consider the matter of energy-payback-time reduction, which means manufacturing a solar cell using energy smaller enough than electric energy generated by the solar cell itself. In this point, the radiation heating does not satisfy this request because the energy consumption easily increases in manufacturing.

[0010] In addition, the radiation heating has the problem of the overshoot in case a feed-back-control of the substrate temperature is carried out, because the substrate temperature rapidly rises up when the substrate is begun to be irradiated. The substrate temperature may settle down at a target value, after exceeding it greatly. If the overshoot happens, much thermal stress is provided to the substrate and at the worst the substrate might be deformed or fractured, or stress might remain in the substrate.

[0011] In addition, it is important to improve accuracy of the temperature control of the substrate during the heating for securing the film quality and the reproducibility. However, it is difficult to control the substrate temperature with high accuracy in the radiation heating. For a high-accuracy control, it is preferable to measure the substrate temperature by a radiation thermometer because of its high-performance. Contrarily, it is difficult to measure the substrate temperature by the radiation thermometer during the radiation heating, because infrared rays reflect on the substrate surface, other than radiant rays proper to the substrate temperature.

[0012] It is also possible to measure the substrate temperature by a thermocouple. However, in many cases, it is impossible to make the thermocouple contact with the substrate. The thermocouple is not suitable for high-accuracy temperature measurement. Especially, when the substrate is placed in a vacuum, the measurement accuracy of the thermocouple decreases, resulting from that temperature difference may occur at the contact points of the substrate and the thermocouple because the atmospheric temperature equalization by the convection cannot be expected.

[0013] In addition, the radiation heating has an essential problem in the solar cell manufacturing. In structure of solar cells, at least one side of a photovoltaic layer needs an optical transparent electrode. For example, in the manufacture of amorphous silicon solar cells, the amorphous silicon film is often deposited on a TCO (Transparent Conductive Oxide) film formed on the substrate. Here, what is problem is that the TCO film has a characteristic of high infrared-ray reflectivity. Therefore, it is essentially impossible to heat the substrate having the TCO film on it by means of the radiation heating with enough efficiency.

[0014] Other than the radiation heating, there is a method utilizing the heat conduction. In this method, a plate with

high thermal conductivity is made contact with the substrate at its backside. This plate is hereinafter called "backing plate". When the backing plate is heated, the substrate is heated through heat transfer by the conduction from the backing plate to the substrate. However, this method cannot be employed in case the backing plate is not used considering the energy-payback-time reduction. In addition, it is difficult to make the baking plate contact with the substrate sufficiently and uniformly. This brings disadvantage that highly efficient and uniform heating is impossible to the backing plate method.

[0015] In addition, by the backing plate method, the substrate is heated only from its backside. As a result, temperature difference in the direction along the substrate thickness easily occurs with thick substrates. Worse, the substrate may suffer a thermal deformation before it is heated up to a required temperature.

[0016] There may be another method where the substrate is heated from both sides by radiation. Even if this method is adopted, it is difficult to keep a balance of heating from both sides because the TCO film that hardly absorbs infrared rays exists on one side of the substrate. Particularly, if this method is carried out placing the substrate under a vacuum pressure, it is almost impossible to heat the substrate from both sides because heat transfer by the convection and the conduction cannot be expected.

SUMMARY OF THE INVENTION

[0017] Object of this invention is to solve problems described above.

[0018] To accomplish this object, the invention presents a thin-film deposition apparatus, comprising; a deposition chamber which is a vacuum chamber where thin-film deposition is carried out on a substrate at a deposition temperature higher than room temperature, and a heat chamber connected directly or indirectly with the deposition chamber, wherein the heat chamber is one which heats the substrate under the atmospheric pressure or a pressure higher than the atmospheric pressure, and has a mechanism to heat the substrate supplying gas of a temperature higher than the room temperature by forced convection.

[0019] To accomplish this object, the invention also presents a thin-film deposition apparatus, comprising; a deposition chamber which is a vacuum chamber where thin-film deposition is carried out on a substrate at a deposition temperature higher than room temperature, a load lock chamber which is a vacuum chamber where the substrate stays temporarily while the substrate is transferred from the atmosphere to the deposition chamber, and a heat chamber which heats the substrate under the atmospheric pressure or a pressure higher than the atmospheric pressure, wherein the heat chamber, the load lock chamber and the deposition chamber are connected directly or indirectly in this order interposing a valve, and the heat chamber has a mechanism to heat the substrate supplying gas of a temperature higher than the room temperature by forced convection.

BRIEF DESCRIPTION OF DRAWINGS

[0020] **FIG. 1** shows a front sectional view of a thin-film deposition apparatus that is an embodiment of the invention.

[0021] **FIG. 2** shows a side schematic view of a transfer mechanism **5**.

[0022] **FIG. 3** shows a side schematic view of a deposition chamber **1**.

[0023] **FIG. 4** shows a side schematic view of a heat chamber **3**.

[0024] **FIG. 5** shows a side schematic view of a load lock chamber **2**.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0025] Preferred embodiments of this invention are described as follows.

[0026] **FIG. 1** shows a front sectional view of a thin-film deposition apparatus as a preferred embodiment of this invention. The apparatus shown in **FIG. 1** comprises a deposition chamber **1** where a thin-film deposition is carried out on substrates **9** at a deposition temperature higher than room temperature, a couple of load lock chamber **2** and unload rock chamber **20** where substrates **9** stay temporarily while substrates **9** are transferred between deposition chamber **1** and an atmosphere, a heat chamber **3** which heats substrates **9** under a pressure higher than the atmospheric pressure. Heat chamber **3**, load lock chamber **2**, deposition chamber **1** and unload rock chamber **20** are connected airtightly in this order interposing valves **4**. A transfer mechanism **5** which transfers substrates **9** between the atmosphere and chambers **3**, **2**, **1**, **20** is provided.

[0027] Valves **4** open and close the openings provided at each boundary between chambers **3**, **2**, **1**, **20** for transferring substrates **9**. As valves **4**, a gate-valve is suitable. The gate-valve is the valve used at a linear vacuum path and can make the path clear with no obstacle remaining when the valve is opened.

[0028] Deposition chamber **1**, load lock chamber **2** and unload rock chamber **20** are vacuum chambers, which comprise a pumping system **11**, **21**, and **201**, respectively. Though heat chamber **3** is an airtight chamber, it has no pumping system.

[0029] The composition of transfer mechanism **5** is described using **FIG. 1** and **FIG. 2**. **FIG. 2** shows a side schematic view of transfer mechanism **5**. Transfer mechanisms **5** is a kind of rack-and-pinion mechanism. Transfer mechanism **5** is mainly composed of a rack board **51** provided horizontally with rack **50** underneath it and pinion mechanism **52** that transfer rack board **51** to a horizontal direction, i.e., vertical to the paper of **FIG. 2**. Each pinion mechanism **52** is composed of a number of pinions **521** engaged with rack **50** and motors **522** that rotate each pinion **521** to move rack board **51** horizontally. Linear guides **54** guiding the movement of rack board **51** are provided.

[0030] As shown in **FIG. 1** and **FIG. 2**, supports **53** are provided uprightly on rack board **51**. Each support **53** has hooks (not shown) holding substrates **9**. A number of pinions **521** are placed at certain intervals along the transfer direction. As shown in **FIG. 1**, pinion mechanisms **52** are provided at one side of the atmosphere, inside of heat chamber **3**, inside of load lock chamber **2**, inside of deposition chamber **1**, inside of unload rock chamber **20** and the other side of the atmosphere. Each pinion mechanism **52** is operated in order so that rack board **51** can be transferred

from one side of the atmosphere to the other side through heat chamber **3**, load lock chamber **2**, deposition chamber **1** and unload rock chamber **20**.

[**0031**] As understood from **FIG. 1** and **FIG. 2**, rack board **51** has a rectangular shape, which length direction is in the transfer direction. Substrates **9** also have a rectangular shape. Substrates **9** are held by supports **53**, making its surface vertical and its length direction along the transfer direction. As shown in **FIG. 2**, six substrates **9** are arranged and held with one rack board **51** in this embodiment. When rack board **51** is moved, six substrates **9** held by supports **53** are transferred at the same time.

[**0032**] A part of transfer mechanism **5** may be provided outside chambers **1**,**2**,**3**,**20**. For example, a mechanism magnetically coupling through a wall of chambers **1**,**2**,**3**,**20** can be adopted. An actuator provided at the atmosphere drives a mechanism holding substrates **9** in chambers **1**,**2**,**3**,**20**. This composition is preferable because mechanisms that are easy to produce dusts or contaminant can be provided outside chambers **1**,**2**,**3**,**20**.

[**0033**] Next, the composition of deposition chamber **1** is described using **FIG. 1** and **FIG. 3**. **FIG. 3** shows a side schematic view of deposition chamber **1**. This embodiment has a composition where an amorphous silicon film is deposited in deposition chamber **1** by the HF plasma CVD method. Here, frequencies between LF (Low Frequency) and UHF (Ultra-High Frequency) are defined as HF (High Efficiency). Specifically, deposition chamber **1** comprises HF electrodes **12** provided in deposition chamber **1**, HF power supplies **13** which apply HF power to HF electrodes **12** and a gas introduction system **14** which introduces the gas mixture of silane and hydrogen into deposition chamber **1**.

[**0034**] HF electrodes **12** are elongated downward from the upper wall of deposition chamber **1**. HF electrodes **12** are antenna-like. Each HF electrode **12** is a U-shaped metal rod. Both ends of each HF electrode **12** are fixed airtightly with insulation block **15** provided at the upper wall of deposition chamber **1**. Both ends of HF electrodes **12** are connected to HF power supplies **13**.

[**0035**] When HF power supplies **13** apply the HF power to HF electrodes **12** in state of the gas mixture of silane and hydrogen introduced by gas introduction system **14**, HF discharges are generated in the gas mixture to form plasmas. Silane decomposes in the plasmas, resulting in that the hydrogenated amorphous silicon film is deposited on the surface of the substrate **9** placed on both sides of HF electrodes **12**.

[**0036**] Points greatly characterizing this embodiment are in the composition of heat chamber **3**. These points are described as follows using **FIG. 4**. **FIG. 4** shows a side schematic view of heat chamber **3**.

[**0037**] One point greatly characterizing this embodiment is that the means of heating is provided not in load lock chamber **2** but in separately provided heat chamber **3**. The means of heating in this embodiment is a heating mechanism **31** provided in heat chamber **3**. Another point greatly characterizing this embodiment is that substrates **9** are heated at a pressure higher than the atmospheric pressure utilizing forced convection.

[**0038**] Specifically, heat chamber **3** comprises valves **4** at each boundary to the atmosphere and to load lock chamber **2**. Pressurizing gas supply system **32** that supplies compressed air or dry air into heat chamber **3** to pressurize it is provided. Heating mechanism **31** in heat chamber **3** is composed mainly of heat source **311**, baffle plates **312**, **313**, **314**, **315** that form an air flow path, and air blower **316** blowing air through the air flow path for circulating inside heat chamber **3**.

[**0039**] Heat source **311** has high energy efficiency such as combustion equipment used with a boiler. Heat source **311** produces heat of 4000 joule/second, i.e., 6000 Kcal/hour, using City gas as fuel. Instead of City gas, liquefied petroleum gas (LPG) may be used as fuel. A centrifugal turbo fan is used as air blower **316**. Baffle plate **312** (hereinafter called the first baffle plate **312**) separates the region at which substrates **9** are placed and the region at which heat source **311** is provided. Heat source **311** is put between baffle plate **312** and baffle plate **313** (hereinafter called the second baffle plate **313**). Baffle plate **314** (hereinafter called the third baffle plate **314**) shuts the space between the upper end of the first baffle plate **312** and the upper end of the second baffle plate **313**. Baffle plate **315** (hereinafter called the fourth baffle plate **315**) shuts the space between the bottom end of the second baffle plate **313** and the wall of heat chamber **3**.

[**0040**] Second baffle plate **313** is provided with a circulation hole **317**. Air blower **316** is fixed on the sidewall of heat chamber **3** at the same height as circulation hole **317**. When air blower **316** is operated, air heated by heat source **311** is inhaled into the upper space through circulation hole **317**.

[**0041**] Filter **33** is provided above the region where substrates **9** are placed. Filter **33** is flush with the third baffle plate **314** at its bottom end. Filter **33** traverses the air flow path. Heated air blowing from air blower **316** flows between the third baffle plate **314** and the upper wall of heat chamber **3**, and reaches to the space above filter **33**. The heated air flows to substrates **9** through filter **33** knocking on the wall of heat chamber **3**, resulting in that substrates **9** are heated.

[**0042**] Filter **33** is used to prevent substrates **9** from contamination. A HEPA filter (High-Efficiency Particle Air filter) with heat-resistance up to about 250° C. is preferably used as filter **33**. A heat insulator is provided at the wall of heat chamber **3** if necessary.

[**0043**] As designated by arrows in **FIG. 4**, the heated air heats substrates **9**, when it flows down from the upper space to the bottom space. Then, the air reaches between the first baffle plate **312** and the second baffle plate **313**, knocking on the bottom wall of heat chamber **3**. Consequently, the air is heated again by heat source **311** and blows out from air blower **316**. Rack board **51** and pinion mechanism **52** are designed to pass the heated air sufficiently.

[**0044**] Substrates **9** are heated higher than the deposition temperature by heating mechanism **31** as described. Showing an example, in case the amorphous silicon film is deposited, the deposition temperature is about 200° C. In this case, substrates **9** must be heated in heating chamber **3** up to about 230° C. Heating mechanism **31** is designed so that the temperature of the heated air can become about 250° C. and the flow rate of the heated air can be maintained at

about 100 m^3 per minute. With this composition, substrates **9** are heated up to about 230° C. within ten to fifteen minutes.

[**0045**] On the other hand, in this embodiment, a temperature-decrease prevention mechanism **22** is provided in load lock chamber **2**. Temperature-decrease prevention mechanism **22** prevents the substrate temperature from decreasing lower than the deposition temperature. This point is described using **FIG. 1** and **FIG. 5**. **FIG. 5** shows a side schematic view of load lock chamber **2**.

[**0046**] Radiation lamp-heaters **221** are employed as temperature-decrease prevention mechanism **22** in this embodiment. Radiation lamp-heaters **221** are rod-shaped filament lamps such as halogen lamps. Radiation lamp-heaters **221** are posed horizontally and aligned vertically. Radiation lamp-heaters **221** are held at both ends together with holders **222** in which a feeding line is provided. Units of radiation lamp-heaters **221** and a couple of holder **222** are arranged between two substrates **9** and between a substrate **9** and the wall of load lock chamber **2**.

[**0047**] When the infrared absorption coefficient of substrates **9** is poor such as in the case substrates **9** have a TCO film as described, it is difficult to heat substrates **9** by radiation lamp-heaters **221**. However, in this embodiment, the heating in load lock chamber **2** is supplementary because heating mechanism **31** in heat chamber **3** heats substrate **9** higher than the deposition temperature. In other words, heating is enough if the substrate temperature does not become lower than the deposition temperature while substrates **9** stay in load lock chamber **2**. Considering this point, radiation lamp-heaters **221** are employed as temperature-decrease prevention mechanism **22** in this embodiment.

[**0048**] Showing a more-detailed example, about fifteen lamps of about 1 kW are used for each substrate **9** as temperature-decrease prevention mechanism **22**, in case that substrates **9** are heated up to about 230° C. in heat chamber **3**, the deposition temperature is 200° C., and substrates **9** are placed in load lock chamber **2** for about nine minutes. In this example, the pressure in load lock chamber **2** is about 1 Pa.

[**0049**] Heating quantity of radiation lamp-heaters **221** is decided according to how high temperature substrates **9** are heated to in heat chamber **3**. In addition, it should be considered how much the substrate temperature decreases by heat dissipation while substrates **9** are transferred from heat chamber **3** to deposition chamber **1**, and how much heat substrates **9** receive from radiation lamp-heaters **221** of temperature-decrease prevention mechanism **22** in load lock chamber **2**. It is preferable that the substrate temperature is just the same as the deposition temperature when substrates **9** reach deposition chamber **1**.

[**0050**] Next, whole operation of the apparatus of this embodiment is described.

[**0051**] To begin with, substrates **9** are set to rack board **51** at a platform (not shown). Each support **53** holds substrates **9**. After the valve **4** on the atmosphere side of heat chamber **3** is opened, transfer mechanism **5** is operated to transfer substrates **9** into heat chamber **3**. The pressure in heat chamber **3** is always maintained a little higher than the atmospheric pressure by pressurizing gas supply system **32**.

[**0052**] After closing the valve **4**, air blower **316** is operated to cause the forced convection, thereby heating substrates **9**. Heat source **311** is operated all the time while the apparatus is available. Air blower **316** may be operated all the time as well.

[**0053**] After heating substrates **9** up to a specified temperature, a valve on pressurizing gas supply system **32** is closed. Substrates **9** are transferred to load lock chamber **2** after valve **4** between heat chamber **3** and load lock chamber **2** is opened. After closing the valve **4**, load lock chamber **2** is pumped by pumping system **21** to a specified vacuum pressure. Substrates **9** are transferred to deposition chamber **1** after valve **4** between load lock chamber **2** and deposition chamber **1** is opened.

[**0054**] Next, after the valve **4** is closed the deposition onto substrates **9** is carried out in deposition chamber **1** as described. Substrates **9** are transferred out to the atmosphere via unload lock chamber **20** after the deposition. Substrates **9** are taken out from each support **53** on rack board **51** at another platform (not shown)

[**0055**] The apparatus of this embodiment described above brings a merit that the energy efficiency is higher and the running cost is cheaper because heating mechanism **31** provided in heat chamber **3** heats substrates **9** not by the radiation but by the forced convection. Particularly, the apparatus of this embodiment is suitable for the manufacture of solar cells for power supply because it requires the energy-payback-time reduction.

[**0056**] Substrates **9** are heated sufficiently even if those infrared ray absorption coefficients are poor as in case of the substrate with the TCO film, because substrates **9** are heated not by the radiation but by the forced convection. This point is another reason why this embodiment is suitable for the manufacture of solar cells.

[**0057**] Problems of the overshoot and the thermal deformation of substrates **9** do not arise in this embodiment, because substrates **9** are not heated rapidly as in case of the radiation heating. In addition, it is possible to measure the substrate temperature with high accuracy by a radiation thermometer. Therefore, the temperature control of substrates **9** can be carried out with high accuracy.

[**0058**] The composition where substrates **9** are heated to a temperature higher than the deposition temperature also contributes to enhancing energy efficiency. It is possible to heat substrates **9** at a temperature lower than the deposition temperature in heat chamber **3** and thereinafter heat substrates **9** up to the deposition temperature in load lock chamber **2** or deposition chamber **1**. However, it is difficult to heat substrates **9** efficiently in load lock chamber **2** or deposition chamber **1** because those are vacuum chambers where the convection heating cannot be utilized. Therefore, heating in load lock chamber **2** or deposition chamber **1** must be the radiation heating. As described, the radiation heating has the low energy efficiency. The radiation heating of the substrate with the TCO film is essentially impossible. Contrarily, when substrates **9** are heated higher than the deposition temperature in heat chamber **3** as in this embodiment, the radiation heating of the low efficiency is not required. Therefore, even the substrate with the TCO film can be heated sufficiently.

[**0059**] The merit of film quality improvement is brought from the composition that substrates **9** are transferred to deposition chamber **1** via load lock chamber **2** after sub-

strates **9** are heated to a temperature higher than the deposition temperature in heat chamber **3**. To heat substrates **9** in heat chamber **3** brings the significance that adsorbed gas can be released sufficiently from substrates **9**. Gas such as water is adsorbed to the surface of substrates **9**. If the deposition is carried out in state that adsorbed gas such as water has not been well released, adsorbed gas would be released rapidly to contaminate the deposited film or to cause a structural defect such as forming bubbles within it. When substrates **9** are heated prior to the deposition, these problems are prevented since adsorbed gas is well released in advance.

[**0060**] Now, how much quantity of adsorbed gas is released depends on how high temperature substrates **9** are heated and how long the temperature is kept. In this embodiment, substrates **9** are heated higher than the deposition temperature in heating chamber **3** and transferred to deposition chamber **1** via load lock chamber **2**, keeping almost the same temperature. Therefore, adsorbed gas is well released from substrates **9** by the time when substrates **9** arrive at deposition chamber **1**. Contrarily, if the adsorbed gas release is carried out only by the heating in load lock chamber **2**, gas release is insufficient because high-temperature keeping time gets shorter. In this case, substrates **9** need to stay longer in load lock chamber **2** so that adsorbed gas can be well released, resulting in that the productivity decreases and the running cost increases. Therefore, this composition is not preferable.

[**0061**] Another merit that substrates **9** are not required to be heated at so high temperature in heat chamber **3** is brought from the composition that temperature-decrease prevention mechanism **22** is provided in load lock chamber **2**. If temperature-decrease prevention mechanism **22** is not provided, there arises necessity to heat substrates **9** at so high temperature calculating the temperature decrease in load lock chamber **2**. In this composition, it would take longer time to heat substrates **9** in heat chamber **3**. Otherwise, heating mechanism **31** would be required to be larger size. The cost of providing temperature-decrease prevention mechanism **22** and the running cost in this embodiment possibly would be cheaper rather than that.

[**0062**] Moreover, another merit that substrates **9** can be restrained from contamination while those are transferred from heat chamber **3** to deposition chamber **1** is brought form the composition that heat chamber **3** is a part of the apparatus, i.e., heat chamber **3** and deposition chamber **1** are connected airtightly. If substrates **9** are temporarily taken out from the apparatus while those are transferred from heat chamber **3** to deposition chamber **1**, substrates **9** may suffer from contamination such as adhesion of contaminants. The possibility of contamination is low when heat chamber **3** is connected with deposition chamber **1** directly or indirectly as shown in this embodiment.

[**0063**] It is possible to employ a chamber layout of the cluster-tool types where load lock chamber **2**, heat chamber **3** and deposition chamber **1** are provided around a transfer chamber in which a transfer robot is provided.

[**0064**] It is also possible to employ the composition where substrates **9** are heated just at the deposition temperature, though those are heated higher than the deposition temperature in this embodiment. The pressure in heat chamber **3** may be the same as the atmospheric pressure. Still, the pressure higher than the atmospheric pressure brings the advantage that contaminants would not be introduced into heat chamber **3**. Inert gas such as nitrogen may be supplied into heat chamber **3** instead of compressed air or dry air at a pressure higher than the atmospheric pressure.

[**0065**] A ceramic heater may be used as temperature-decrease prevention mechanism **22** instead of radiation lamp-heaters **221**. The heating in load lock chamber **2** can be abolished by heating substrates **9** in heat chamber **3** at a temperature higher enough than the deposition temperature. A specified heat-insulation mechanism may be used as temperature-decrease prevention mechanism **22** in load loch chamber **2**.

[**0066**] Other than the hydrogenated amorphous silicon film deposition as described, the apparatus of the invention can carry out another amorphous silicon film deposition such as amorphous silicon fluoride film deposition, amorphous silicon carbide film deposition, amorphous silicon germanium firm deposition and the like. Phosphorus doped films or boron doped films also can be deposited by the apparatus of the invention.

[**0067**] The apparatus of the invention can be used for manufacture of liquid crystal displays or information storage disks other than solar cells. For example, the composition of the heating in this invention can be used for a thin-film deposition for a driver electrode in a LCD. Especially, sufficient gas release is required when an indium-tin-Oxide (ITO) film is deposited by sputtering on a substrate with a color filter formed on it, because the color filter involves much water. Therefore, the apparatus of the invention that can carry out the gas release efficiently is suitable.

[**0068**] The composition of deposition chamber **1** is optimized according to a kind of deposition process. For example, a CVD not by an inductive coupled plasma but by a capacitive coupled plasma may be adopted. Physical depositions such as sputtering or ion-beam deposition can be adopted as well.

What is claimed is:

1. A thin-film deposition apparatus, comprising;

a deposition chamber which is a vacuum chamber where thin-film deposition is carried out on a substrate at a deposition temperature higher than room temperature; and

a heat chamber connected directly or indirectly with said deposition chamber; wherein

said heat chamber is one which heats said substrate under atmospheric pressure or a pressure higher than said atmospheric pressure, and has a mechanism to heat said substrate supplying gas of a temperature higher than said room temperature by forced convection.

2. A thin-film deposition apparatus as claimed in claim 1, wherein;

said heating mechanism is one which heats said substrate at said deposition temperature or a temperature higher than said deposition temperature.

3. A thin-film deposition apparatus as claimed in claim 1 or claim 2, wherein;

said substrate is used for manufacture of a solar cell.

4. A thin-film deposition apparatus comprising;

a deposition chamber which is a vacuum chamber where thin-film deposition is carried out on a substrate at a deposition temperature higher than room temperature;

a load lock chamber which is a vacuum chamber where said substrate stays temporarily while said substrate is transferred from an atmosphere to said deposition chamber; and

a heat chamber which heats said substrate under atmospheric pressure or a pressure higher than said atmospheric pressure; wherein

said heat chamber, said load lock chamber and said deposition chamber are connected directly or indirectly in this order interposing a valve; and

said heat chamber has a mechanism to heat said substrate supplying gas of a temperature higher than said room temperature by forced convection.

5. A thin-film deposition apparatus as claimed in claim 4, wherein;

said heating mechanism is one which heats said substrate at said deposition temperature or a temperature higher than said deposition temperature.

6. A thin-film deposition apparatus as claimed in claim 5, wherein;

a temperature-decrease prevention mechanism which prevents temperature of said substrate from decreasing lower than said deposition temperature is provided in said load lock chamber.

7. A thin-film deposition apparatus as claimed in claim 4, claim 5 or claim 6, wherein;

said substrate is used for manufacture of a solar cell.

* * * * *