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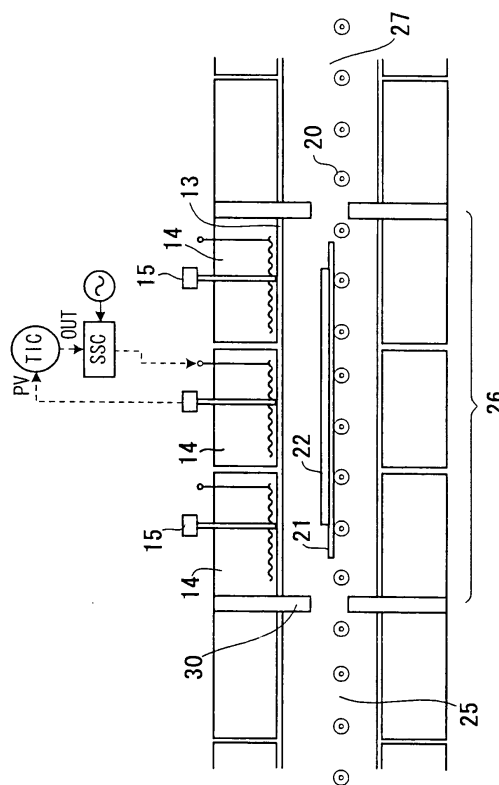
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(54) **Heat treatment method and heat treatment furnace for plasma display panel substrate**

(57) A heat treatment method for performing a uniform heat treatment on the whole substrate (22), by carrying out temperature control in such a manner that the temperatures of each of the respective heating means (14) provided in the heating chamber (25,26,27) are set at different values in the transporting direction of the object (22) to be thermally treated, and maintaining temperatures in the chamber (25,26,27) larger in deviation in temperature distribution than a target temperature distribution within the substrate (22) by using a heat treatment furnace. The furnace comprises a plurality of sectioned heating chambers (25,26,27); transporting means (20) for transporting the substrate (22) to the next heating chamber (25,26,27); and separated heating means (14) provided in each heating chamber (25,26,27) in the transporting direction; each heating means (14) being capable of separately controlling a temperature by an independent control system; and a radiant heating means for selectively heating the portion lower in atmosphere temperature.

FIG. 6



EP 1 439 563 A2

Description

BACKGROUND OF THE INVENTION

5 Field of the Invention

[0001] The present invention relates to a heat treatment method for a substrate containing a film-forming material typified by a glass substrate for a plasma display panel and a heat treatment furnace usable therefor.

10 Description of the Related Art

[0002] Recently, a large-screen flat panel display (hereinafter referred to as "FPD"), which may be used as a wall-hung type TV set or a multimedia display, has been proceeding toward its practical utilization in a steady progress. As such a large-screen FPD, a plasma display panel (hereinafter referred to as "PDP") is expected as the most promising candidate, thanks to its self-emitting feature with a wide viewing angle, and its combined advantage of a good display quality and its manufacturing advantage of a simple formation process as well as easy upsizing of the panel.

[0003] As illustrated in FIG. 3, for example, the manufacturing of PDP is done by means of a thick film method, where each step of printing, drying, and burning is repeated in a plural number of times on surfaces of both front glass and rear glass for a glass substrate of a large-size display in order to form a variety of members such as electrodes, dielectric substances, fluorescent substances, etc. thereon. Thereafter, thus processed front glass and rear glass are sealed each other at the final step.

[0004] In heat treatment of a substrate containing a film-forming material such as this PDP glass substrate, a substrate is continuously transported during steps when the temperature difference between the front portion and the rear portion of the substrate in the transporting direction thereof is not so serious. However, in steps where the temperature difference between the front portion and the rear portion of the substrate in the transporting direction thereof is thought to be serious, it is a common practice to employ a method wherein temperature is raised, kept at a given level, or lowered in accordance with a desired temperature curve for heat treatment by separately controlling the temperature of each heating chamber, in a finance being provided with a plurality of heating chambers sectioned in a transportation direction of an object to be thermally treated, and transporting means for transporting the object to be thermally treated in an intermittent manner to a next heating chamber.

[0005] The reason why heat treatment is done by using sectioned heating chambers like these is to make the surface temperature of a substrate in each heating chamber as uniform as possible. If heat treatment is done under a condition where the deviation in the temperature distribution among the substrate surface is large, the distortion may often occur on the substrate itself or members such as films, which might cause defects such as cracking or chipping. Generally, each heating chamber has a space enough to house one plate of a setter which carries a substrate, and there is provided with a certain number of separated heating means at predetermined positions therein in the transporting direction of the object to be thermally treated (i. e., the direction of the length of the furnace; hereinafter referred to as the transporting direction of the object to be thermally treated) and in the direction of the width of the furnace.

[0006] These separated heating means are generally configured to allow each of themselves to be separately controlled in terms of temperature with an independent control system, whereas conventional temperature control of each heating device has been done in such a way that the atmosphere temperature (hereinafter often simply referred to as temperature) in each sectioned heating chamber becomes uniform according to the conventional heat treatment method of a substrate containing a film-forming material (See Japanese Patent No. 3011366).

[0007] While it is popular to build a partition each between heating chambers in order to reduce thermal effects from adjacent heating chambers on both sides, it is hardly possible to shut off mutual thermal effects thereof on each other completely. For this reason, even if one tries to make temperature in each heating chamber keep at a given level by controlling heating means strictly in case of the conventional finance, the temperature of a substrate subjected to heat treatment for a predetermined time duration in the heating chamber tends to vary, depending upon the positions of the surface in the transporting direction thereof due to thermal effects from its preceding adjacent other chamber. Therefore, the conventional method has a problem that the uniform quality in heat treatment can not be attained.

[0008] In addition, because it takes tens of seconds or a couple of minutes for a substrate to be transported to a next heating chamber regardless of which transporting means is adopted, whether it is a roller conveyor, a chain conveyor, a walking beam, it is inevitable that heat history varies between the front portion of the substrate in the transporting direction which is delivered earlier to the transport-destination heating chamber, that is, the portion of the substrate closer to the exit side of the furnace in the transporting direction), and the rear portion in the transporting direction which is delivered later to the transport-destination heating chamber, that is, the portion of the substrate closer to the entrance side of the furnace in the transporting direction when transporting the substrate between adjacent heating chambers having the set temperatures different from each other. As a consequence, it causes another problem that

the deviation in the temperature distribution within the substrate occurs.

SUMMARY OF THE INVENTION

[0009] The present invention has been developed in view of such conventional circumstances, and an object of the present invention is to provide a substrate heat treatment method which makes it possible to suppress the development of the deviation in the temperature distribution within the substrate due to thermal effects derived from a preceding adjacent heating chamber having a different inner chamber average temperature and to achieve a uniform heat treatment on the entire surface of the substrate when subjecting the substrate containing a film-forming material to a heat treatment in a heating chamber. Another object of the present invention is to provide a heat treatment furnace suitably applicable to such a heat treatment method.

[0010] According to the present invention, there is provided a heat treatment method of a substrate containing a film-forming material by use of a heat treatment furnace comprising a plurality of heating chambers sectioned in a transporting direction of an object to be thermally treated; transporting means for transporting the object to be thermally treated to a next heating chamber; and a predetermined number of separated heating means in each heating chamber at predetermined positions in the transporting direction of the object to be thermally treated, each heating means being capable of separately controlling a temperature by an independent control system; wherein among the plurality of heating chambers, in a heating chamber required to be different in inside average temperature from that of at least one of the adjacent heating chambers on both sides, the substrate is uniformly thermally treated by carrying out temperature control in such a manner that temperature each of the respective heating means provided in the heating chamber is set at different values in the transporting direction of the object to be thermally treated and atmosphere temperatures at an entrance side and an exit side of the transporting direction of the substrate may be maintained in the heating chamber at such a level that it is larger in the difference of the temperature distribution than a deviation in a target temperature distribution within the substrate.

[0011] Furthermore, according to the present invention, there is provided a heat treatment furnace having a plurality of heating chambers each of which is sectioned in a transporting direction of an object to be thermally treated, transporting means for transporting the object to be thermally treated to a next adjacent heating chamber, and a predetermined number of separated heating means located at predetermined positions in each heating chamber in the transporting direction of the object to be thermally treated, each heating means being capable of separately controlling a temperature of a target position of a substrate to be thermally treated by an independent control system, the heat treatment furnace further comprising a temperature control device being controllable in such a manner that temperature each of the respective heating means provided at the predetermined position in the heating chamber may be set at different values in the transporting direction of the object to be thermally treated; and a radiant heater for mainly generating radiant heat which is heating means for heating a side lower in temperature between an entrance side and an exit side of the substrate to be treated in the transporting direction of the substrate in the heating chamber; wherein a substrate is uniformly thermally treated by utilizing radiant heat of the radiant heater for heating a lower temperature side of the heating chamber without making distribution of atmosphere temperature in the heating chamber evenly.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

FIG. 1 is an illustrative diagram showing one example of embodiments according to a heat treatment method of the present invention, where (a) illustrates the general structure of heating means, (b) illustrates the set temperature of heating means under a flat setting, (c) illustrates the set temperature of heating means under an inclined setting, and (d) illustrates a glass substrate, which is an object to be thermally treated, and the places where thermometers were set on the substrate;

FIG. 2 is an illustrative diagram showing the set temperature distribution of each heating means in a heating chamber, inner-chamber temperature distribution (atmosphere temperature distribution), and the temperature distribution in a substrate;

FIG. 3 is a flowchart illustrating the manufacturing process of a PDP;

FIG. 4 is a graph representing the infrared rays irradiation rate of Si-impregnated SiC;

FIG. 5 is a sectional view taken along the direction perpendicular to the substrate transporting direction, which illustratively shows one embodiment of a heat treatment furnace according to the present invention; and

FIG. 6 is a transverse sectional view taken along the direction parallel to the substrate transporting direction of the embodiment illustrated in FIG. 5.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0013] A heat treatment furnace to be employed in the present invention has a plurality of heating chambers sectioned in the transporting direction of an object to be thermally treated, and transporting means for transporting the object to be thermally treated to a next heating chamber. Each heating chamber is provided with a predetermined number of separated heating means at predetermined positions in the transporting direction of the object to be thermally treated. Each of the heating means is configured to be capable of separately controlling a temperature by an independent control system.

[0014] It is to be noted that, as the transporting means, it is preferable to adopt an intermittent transport mode transporting means, which transports an object to be thermally treated to a next heating chamber in an intermittent manner. Herein, the expression "transports (something) in an intermittent manner" means a manner of a transportation which repeats the procedures which comprise the step of subjecting an object to be thermally treated to heat treatment for a predetermined period of time in the n-th heating chamber, counted from the entrance side of a furnace, while having the object to be thermally treated standing still thereat, subsequently moving the object to be thermally treated to the n+1-th heating chamber, counted from the entrance side of the furnace, as soon as possible thereafter, and subjecting the object to be thermally treated a heat treatment for a predetermined period of time by having the object to be thermally treated standing still again. As far as such a transport method may be carried out, there is no specific limitation on the type of transporting means, and for example, a walking beam may be used, or a roller conveyor or a chain conveyor may be driven intermittently.

[0015] According to a heat treatment method of the present invention, among a plurality of heating chambers sectioned as described above, in a heating chamber required to be different in an inside average temperature of the heating chamber from that of at least one of adjacent heating chambers on both sides (either one of a heating chamber which is adjacent thereto in the entrance side direction of a furnace and another heating chamber which is adjacent thereto in the exit side direction of the furnace, or both of them), temperature of each heating means provided in the heating chamber is controlled in such a manner that temperature each of the heating means provided in the heating chamber is set at different values in the transporting direction of the object to be thermally treated, and by such controlling, in the heating chamber, the deviation in the distribution of atmosphere temperatures at the entrance side and that at the exit side of the transporting direction of the substrate are tolerated to be larger distribution than a target temperature distribution in the substrate. In the other words, no attempt is made to uniform a temperature (atmosphere temperature) distribution in the heating chamber, and instead, the radiant heat of heating means such as a radiant heater, etc., is utilized for applying heat to a substrate at the side lower in the inner temperature so as to offset thermal effects from adjacent heating chambers on both sides on a substrate containing a film-forming material under heat treatment in the heating chamber.

[0016] That is, generally, a substrate containing a film-forming material such as a PDP glass substrate is subjected to heat treatment by going through steps of raising temperature, keeping it at a given level, and lowering temperature (cooling) in accordance with a desired temperature curve while moving it through each heating chamber sequentially, and for example, in a heating chamber in a temperature-lowering region where the temperature of a substrate is dropped, the closer to the exit side of a furnace, the lower the inner temperature is set therein, and accordingly, a substrate transported to a heating chamber in a temperature-lowering region receives thermal effects from its preceding adjacent heating chamber having a higher inner chamber average temperature located on the position closer to the entrance side of the furnace, thereby the substrate temperature tending to become higher than a target value, and contrarily, it receives thermal effects from its next adjacent heating chamber having a lower inner chamber average temperature on the position closer to the exit side of the furnace, thereby the substrate temperature tending to become lower than a target value.

[0017] Therefore, even if the temperatures of heating means are controlled so as to achieve uniformity in temperature between each of heating chambers as have been done conventionally, some deviation in distribution of temperature within a substrate in its transporting direction will be developed due to thermal effects on the substrate from its adjacent heating chambers on both sides, which would cause defects such as warps in the substrate itself or in a film formed on the substrate, a crack, a chip, and so forth.

[0018] In an effort to deal with that, according to a heat treatment method of the present invention, the set temperature of each heating means provided at a predetermined position in a specified heating chamber is controlled to become a different value from each other in the transporting direction of an object to be thermally treated, which is achieved in such a manner that, for heating means that applies heat to a portion where the substrate temperature tends to become lower than a target value due to thermal effects from the adjacent heating chamber(s) at either side or both sides, the set temperature thereof is controlled to become a higher value in order to offset a drop in temperature due to its thermal effects, thereby raising the atmosphere temperature surrounding the portion, and contrarily, for heating means that applies heat to a portion where the substrate temperature tends to become higher than a target value due to thermal effects from the adjacent heating chamber(s) at either side or both sides, the set temperature thereof is controlled to

become a lower value in order to offset a raise in temperature due to its thermal effects, thereby lowering the atmosphere temperature surrounding the portion.

[0019] Note that one may choose the necessary number of the heating means to be provided in a specified sectioned heating chamber at a proper position, taking into consideration the size of the substrate to be thermally treated and temperature range to be controlled and the like. The same thing would be applicable to the position for installing respective heating means. Indeed, one may set a temperature of all the heating means for at least one of the portions among the front, middle and rear portions of the substrate at the same temperature value, while keeping the temperature of the respective portions at different level in case of need.

[0020] The inventors have conceived that, instead of attempting to uniform the distribution of atmosphere temperature in a heating chamber, it is possible to carry out a uniform heat treatment of a substrate, which is consequently achieved by utilizing the radiant heat by means of heating means such as a radiant heater, etc., more heavily for applying heat to the side of the substrate which is lower in the inner atmosphere temperature.

[0021] For example, in a case where the heat treatment on a 40-inch PDP glass substrate is done with heating means separated into nine as denoted with A - I in FIG. 1(a), each heating means being capable of separately controlling a temperature by an independent control system, located at the top side (furnace ceiling) of a heating chamber in a temperature-lowering region having a deviation in its inner chamber average temperature of 30°C from its preceding adjacent heating chamber, the temperature distribution of a substrate after heat application for a predetermined time duration is studied under a condition as illustrated in FIG. 1(b), where all of the set temperatures for the separated heating means A - I are equal (flat setting) and under a condition as illustrated in FIG. 1(c), where the set temperatures for the entrance side heating means G - I are a lower value (500°C) in comparison with the set temperatures for the center heating means D - F (510°C) while the set temperatures for the exit side heating means A - C are a higher value (530°C) in comparison with the set temperatures for the center heating means D - F (510°C) (inclined setting); as the findings of the study, TABLE 1 below shows the temperatures and their deviation of nine specific points on the glass substrate denoted as (1) - (9) in FIG. 1(d) where thermometers were disposed, indicating a smaller temperature distribution in the substrate under the inclined setting than under the flat setting. Also under such settings, a measurement was taken on the temperatures of points in space 50cm above each (1) - (9) in FIG. 1(d), which indicates, as shown in TABLE 2, that the temperature distribution in the heating chamber was larger than the temperature distribution in the substrate.

TABLE 1

	Measurement Value (°C)									Deviation
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	
Flat Temp.	527	529	522	511	520	510	504	510	508	25
Inclined Temp.	518	520	517	517	519	515	514	515	514	6

TABLE 2

	Measurement Value (°C)									Deviation
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	
Flat Temp.	515	514	511	497	505	500	487	492	485	29
Inclined Temp.	512	513	513	503	508	505	498	502	496	17

[0022] As described above, according to a heat treatment method of the present invention, in the same single heating chamber, the set temperature of each separated heating means is controlled so that values thereof differ in the transporting direction of an object to be thermally treated, and in the heating chamber, the temperatures at the entrance side and at the exit side of the transporting direction of the substrate are controlled to have a larger distribution than a target temperature distribution in the substrate, for example, the set temperature of each heating means is controlled so that they have a temperature difference of $\Delta 30^{\circ}\text{C}$ between at the entrance side and at the exit side, and by such controlling, a temperature difference of $\Delta 17^{\circ}\text{C}$ between the entrance side and the exit side is tolerated as the atmosphere temperature distribution in the heating chamber, that is, without attempting to make the distribution in atmosphere temperature in the heating chamber evenly, and instead, the radiant heat of heating means such as a radiant heater, etc., is utilized for applying heat to a substrate at the lower inner temperature side more heavily than for applying heat to other substrate portions with other heating means for the purpose of achieving a uniform heat application, thereby ensuring that the difference in the temperature of the substrate portion having the highest temperature and the tem-

perature of the substrate portion having the lowest temperature, denoted as ΔT , falls within a range of 6°C or less to offset thermal effects from the preceding adjacent heating chambers.

[0023] Herein, in order to ensure that the difference in the temperature of the substrate portion having the highest temperature and the temperature of the substrate portion having the lowest temperature, denoted as ΔT , falls within a range of 6°C or less, it is preferable to hold a temperature difference within approximately $\Delta 7^\circ\text{C}$ through $\Delta 20^\circ\text{C}$ as the distribution of atmosphere temperature in the heating chamber even when the radiant heat is more heavily utilized for applying heat to the substrate at the lower inner temperature side, and it is more preferable to keep it within $\Delta 8^\circ\text{C}$ through $\Delta 15^\circ\text{C}$. Incidentally, the above study findings shown in TABLE 1 and TABLE 2 are obtained just with a guide temperature difference, and it goes without saying that temperature difference in the front and rear portions of the substrate in the transporting direction thereof and the temperature difference in its width direction may be further reduced by making fine adjustment of the set temperature of the heating means.

[0024] According to a heat treatment method of the present invention, as it is possible to offset thermal effects from the preceding adjacent heating chamber. In other words, as it is possible to sacrifice thermal separation between a heating chamber and its adjacent heating chambers on both sides to some degree, there is a further advantage in that it is possible to transport a substrate from a heating chamber to the next adjacent heating chamber in a speedy and effective manner.

[0025] In a heat treatment method of the present invention, if an attempt were made to uniform the atmosphere temperature distribution in the heating chamber within a range of $\Delta 6^\circ\text{C}$ by setting the set temperature(s) of heating means at the lower inner temperature side higher to make the temperature difference larger than $\Delta 30^\circ\text{C}$, it would be undesirable due to excessive thermal effects from adjacent heating chamber(s) at either side or both sides. It is noted that, as for a heating chamber in a temperature-raising region where temperature is raised on a substrate, it is possible to achieve a uniform heat application by making settings contrary to the above example, that is, by controlling the set temperature(s) of heating means at the entrance side to be a higher value(s) while controlling the set temperature(s) of heating means at the exit side to be a lower value(s).

[0026] In addition, in a case where the temperature distribution in a substrate is developed also in the width direction of a furnace due to thermal effects from furnace walls, etc., it is still possible to perform a uniform heat treatment with a thermal effect offset, achieved by separating heating means not only in the transporting direction of an object to be thermally treated (along the length direction of such a furnace) but also along the width direction of the furnace, and by controlling the set temperature of each heating means into a different value also along its width direction.

[0027] Next, an explanation is given below on a heat treatment furnace usable suitably for carrying out a heat treatment method according to the present invention. A heat treatment furnace suitable for a heat treatment method according to the present invention comprises, as its basic configuration components, a plurality of sectioned heating chambers provided in the transporting direction of an object to be thermally treated, and transporting means for transporting the object to be thermally treated to a next heating chamber. Provided in each heating chamber are a predetermined number of heating means located at predetermined positions in the transporting direction of the object to be thermally treated, where each of the separated heating means is capable of separately controlling a temperature by an independent control system.

[0028] In addition, this heat treatment furnace further comprises, as its characteristic configuration components, a temperature control device capable of controlling temperature each of a plural number of separated heating means provided at the predetermined position in the heating chamber so as to set temperature at a value different each other in the transporting direction of an object to be thermally treated, and a radiant heater that mainly emits radiant heat as heating means employed at a side lower in temperature in the heating chamber, and with such a configuration, it is possible to achieve the objective of a uniform heat treatment on a substrate by utilizing the radiant heat of the radiant heater for applying heat to the side lower in inner chamber temperature without controlling the distribution of atmosphere temperature evenly in the heating chamber.

[0029] It is to be noted that, under the present invention, although it is acceptable to use normal heaters as heating means, it is preferable to adopt such a type of radiant heater(s) that mainly emits radiant heat as heating means employed at the side of the lower temperature in the heating chamber. With such a configuration, as described above, even under a condition where the distribution of temperature in a heating chamber is not uniform, it is still possible to achieve a uniform heat application to a substrate by utilizing the radiant heat of heating means such as a radiant heater, etc., for applying heat to the substrate at a side lower in inner temperature more heavily than for applying heat to other substrate portions with other heating means to ensure that the difference in the temperature of the substrate portion having the highest temperature and the temperature of the substrate portion having the lowest temperature falls within a range of 6°C or less while suppressing thermal effects from the preceding adjacent heating chamber at a minimum level.

[0030] It is preferable to place a muffle capable of covering each area between each heating means and each moving zone for an object to be thermally treated, and more preferably, it is ideal that the part of or the entirety of the muffle is made up of a material having a high infrared rays irradiation rate. This is because, with such a muffle once absorbing

heat emitted from the heating means and then radiating far-infrared rays or near-infrared rays, it is possible to speedily heat the object to be thermally treated. Furthermore, it produces an additional effect of ensuring cleanness in the moving area of the object to be thermally treated by isolating the moving area of the object to be thermally treated from the heating means hermetically with the muffle.

[0031] As a material having a high infrared rays irradiation rate which makes up a muffle, a sintered compact containing SiC is preferable, and among others, Si-impregnated SiC is more preferred. Si-impregnated SiC is obtained by sintering a compact containing silicon carbide and carbon as its main component in a pressure-reduced inert gas atmosphere with metal silicon existent therein or in a vacuum while impregnating it with metal silicon; and as illustrated in FIG. 4, this material shows a remarkably higher infrared rays irradiation rate in comparison with, for example, glass ceramics, and in addition to that, it also features a very high thermal conductivity.

[0032] As transporting means, as described above, there is intermittent transport mode transporting means, which intermittently transports an object to be thermally treated, and continuous transport mode transporting means, which transports an object to be thermally treated continuously with the object moving constantly without standing still in each heating chamber. Although intermittent transport mode transporting means is suitably adopted in the present invention, it may alternatively be configured so that both of the different transport modes are used suitably according to regions, as in a case where continuous transport mode transporting means is used for transporting between heating chambers in a temperature-raising region where temperature is raised on an object to be thermally treated and in a temperature-keeping region where temperature is maintained on an object to be thermally treated, whereas intermittent transport mode transporting means is used for transporting between heating chambers in a temperature-lowering region where temperature is lowered (cooled down) on an object to be thermally treated.

[0033] FIG. 5 is a sectional view taken along the direction perpendicular to the substrate transporting direction, which specifically indicates one embodiment of a heat treatment furnace according to the present invention; and FIG. 6 is a transverse sectional view taken along the direction parallel to the substrate transporting direction of the present embodiment.

[0034] In FIG. 5 and FIG. 6, a heat treatment furnace 10 comprises a furnace can 11 formed mainly from a steel plate, a heat insulating layer 12 disposed in the furnace can 11, and a muffle 13 disposed in the heat insulating layer 12 and at a position facing a space in the furnace. In addition, heating electric heaters 14 are provided at the top side and the bottom side of the heat treatment furnace 10. Further, thermoelectric couples 15 as thermometers in the device shown in these figures for controlling the heat value of the heating electric heaters 14 are disposed in such positions where each of their tips is in contact with the muffle 13. Outside the furnace can 11, a return conveyor 16 for transporting an object to be thermally treated 22 is disposed below the furnace can 11, and a control panel 17 and a wiring pipe 18 are disposed at the sides of the furnace can 11, with all these elements covered with a decorative sheet 19.

[0035] A PDP substrate 22, which is an object to be thermally treated, carried by a setter 21, moves along an inner-furnace transporting plane inside the furnace 10, driven by the turning of a plurality of transporting rollers 20 arranged therein, and is subjected to sintering processing by the heating electric heaters 14. Incidentally, a move support section 23, which bears the weight of the transporting rollers 20 and holds its flexible turning, is provided outside the furnace can 11, and a drive section 24, which bears the weight of the transporting rollers 20 on the other end and gives a turning force to the rollers 20, is also provided.

[0036] As illustrated in FIG. 6, the heat treatment furnace 10 has a plurality of heating chambers wherein the chambers are shown with the referential numbers 25, 26, 27, and the like, and they are sectioned in the transporting direction of the object to be thermally treated 22, and in each of the heating chambers, the heating electric heaters 14, which are sectioned into three, as shown for the heating chamber 26, in the transporting direction of the object to be thermally treated 22, are provided. Incidentally, reference numeral 30 denotes a partition wall, which is provided in between each of the heating chambers 25, 26, 27, and the like to serve the function of heat separation between a heating chamber and its adjacent heating chamber on both sides to a predetermined degree. Note that the number of the heating chambers to be provided may be properly chosen, depending on the number of heating treatment, heat treatment conditions and the like.

[0037] In the above configuration, the temperature of the muffle 13 measured with the thermoelectric couple 15 is inputted into a temperature controller TIC provided in the control panel 17, and its control output is inputted into a control unit SSC. Then, at the control unit SSC, the temperature of the muffle 13 is maintained at a target temperature by feeding required power to the heating electric heaters 14. Herein, the temperature controller TIC and the control unit SSC are individually disposed for each of the heating electric heaters 14, or for each group of a plurality of the heating electric heaters 14. In this way, in each of the heating chambers 25, 26, 27, and the like, it is possible to perform an individual temperature control by three separated heating electric heaters 14, each controlled by means of an independent control system.

[0038] As described above, according to the present invention, when heat-treating a substrate containing a film-forming material in a heating chamber, it is possible to suppress the development of a temperature distribution in the substrate due to thermal effects from its adjacent heating chamber on both sides having a different inner chamber

average temperature, which makes it further possible to perform a uniform heat treatment on the whole substrate. Moreover, according to a heat treatment method and a heat treatment furnace of the present invention, it is possible to offset thermal effects from adjacent heating chambers on both sides, and accordingly, it is also possible to sacrifice thermal separation between a heating chamber and adjacent heating chambers on both sides to some degree to offer a further advantage in that it is possible to transport a substrate from a heating chamber to its adjacent heating chamber in a speedy and effective manner.

[0039] A heat treatment method for performing a uniform heat treatment on the whole substrate, which comprises carrying out temperature control in such a manner that temperature each of the respective heating means provided in the heating chamber by setting temperature of them at different values in the transporting direction of the object to be thermally treated, and maintaining temperatures in the chamber larger in deviation in temperature distribution than a target temperature distribution within the substrate by using a heat treatment furnace. The furnace comprises a plurality of sectioned heating chambers; transporting means for transporting the substrate to next heating chamber; and separated heating means provided in each heating chamber in the transporting direction; each heating means being separately controllable a temperature by an independent control system; and a radiant heating means for selectively

Claims

1. A heat treatment method of a substrate containing a film-forming material by use of a heat treatment furnace comprising a plurality of heating chambers sectioned in a transporting direction of an object to be thermally treated; transporting means for transporting the object to be thermally treated to a next heating chamber; and a predetermined number of separated heating means located at predetermined positions in each heating chamber in the transporting direction of the object to be thermally treated, each heating means being capable of separately controlling a temperature by an independent control system;

wherein among the plurality of heating chambers, in a heating chamber required to be different in inside average temperature from that of at least one of adjacent heating chambers at both sides, a substrate is uniformly thermally treated by carrying out temperature control in such a manner that temperature each of the respective heating means provided in the heating chamber is set at a different value in the transporting direction of the object to be thermally treated and atmosphere temperatures at an entrance side and an exit side of the transporting direction of the substrate may be maintained in the heating chamber at such level that it is larger in deviation in temperature distribution than a target temperature distribution within the substrate.

2. The heat treatment method according to claim 1, wherein the substrate is subjected to uniformly thermal treatment without making atmosphere temperature distribution in the heating chamber evenly, by utilizing radiant heat of the heating means for applying heat to a side in lower in an inner chamber temperature.

3. The heat treatment method according to claim 1 or 2, wherein the transporting means is an intermittent transport mode transporting means, which transports an object to be thermally treated to a next heating chamber in an intermittent manner.

4. The heat treatment method according to any one of claims 1 to 3, wherein a set temperature of each heating means provided in a heating chamber is controlled in such a manner that ΔT as a difference between temperature of a substrate portion having highest temperature and temperature of a substrate portion having lowest temperature in a heating chamber for lowering temperature is within a range of 6°C or less when the substrate is kept in the heating chamber, in case of subjecting the substrate to heat treatment in steps of raising temperature, keeping it within a predetermined range, and lowering temperature.

5. A heat treatment furnace having a plurality of heating chambers each of which is sectioned in a transporting direction of an object to be thermally treated, transporting means for transporting the object to be thermally treated to a next heating chamber, and a predetermined number of separated heating means located at predetermined positions in each heating chamber in the transporting direction of the object to be thermally treated, each heating means being capable of separately controlling a temperature by an independent control system,

the heat treatment furnace further comprising a temperature control device being controllable temperature each of the respective heating means provided at predetermined positions in the heating chamber may be set at different values in the transporting direction of the object to be thermally treated; and

a radiant heater for mainly generating radiant heat which is heating means for heating a side lower in temperature between an entrance side and an exit side in the transporting direction of the substrate in the heating chamber;

wherein the substrate is uniformly thermally treated by utilizing radiant heat of the radiant heater for heating a lower temperature side of the heating chamber without making distribution of atmosphere temperature in the heating chamber evenly.

- 5 **6.** The heat treatment furnace according to claim 5, wherein a muffle is disposed at an area between the heating means and a moving zone of an object to be thermally treated, the part of or the entirety of the muffle being made up of a material having a high infrared rays irradiation rate.
- 10 **7.** The heat treatment furnace according to claim 6, wherein the material having a high infrared rays irradiation rate is a sintered compact containing SiC.
- 15 **8.** The heat treatment furnace according to any one of claims 5 to 7, wherein the transporting means is an intermittent transport mode transporting means, which transports an object to be thermally treated to a next heating chamber in an intermittent manner.
- 20 **9.** The heat treatment furnace according to any one of claims 5 to 8, wherein a continuous transport mode transporting means is used for transporting between heating chambers in a temperature-raising region where temperature is raised on an object to be thermally treated, while an intermittent transport mode transporting means is used for transporting between heating chambers in a temperature-lowering region where temperature is lowered on the object to be thermally treated.

FIG. 1(a)

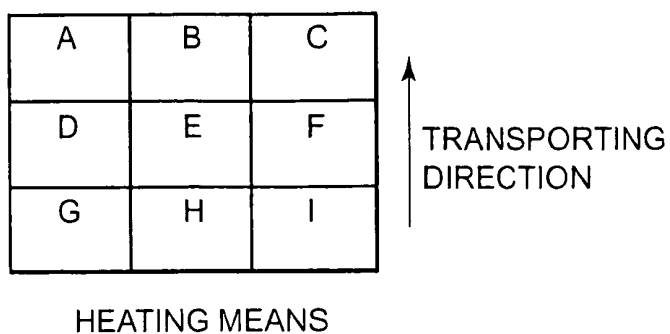


FIG. 1(b)

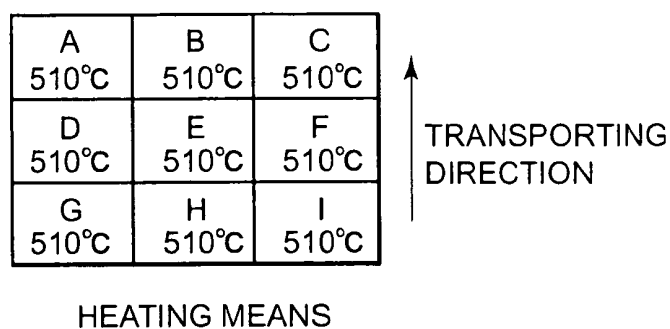


FIG. 1(c)

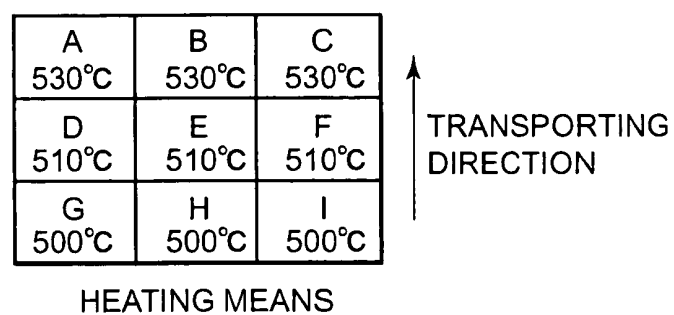


FIG. 1(d)

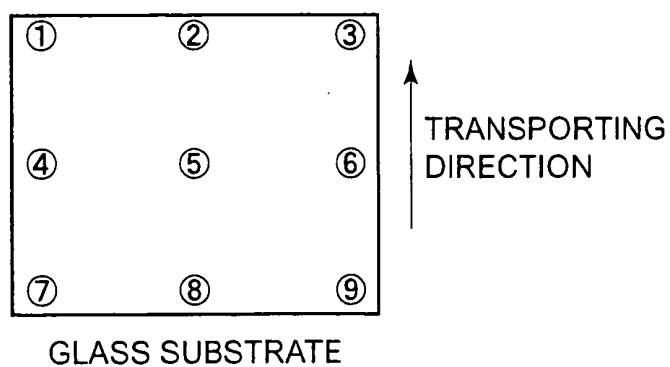


FIG. 2

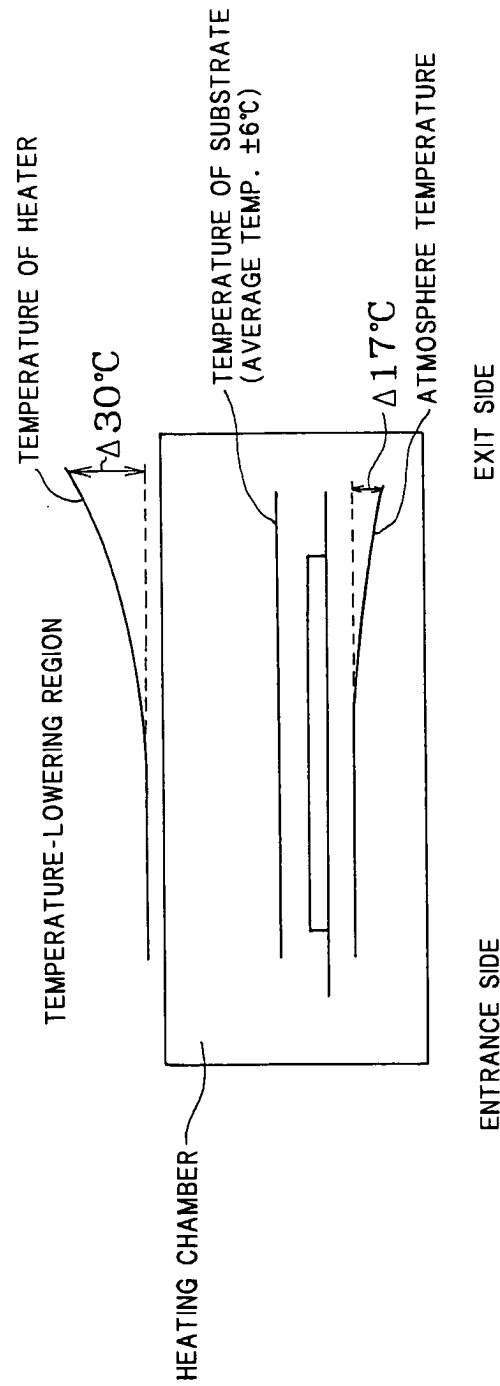


FIG. 3

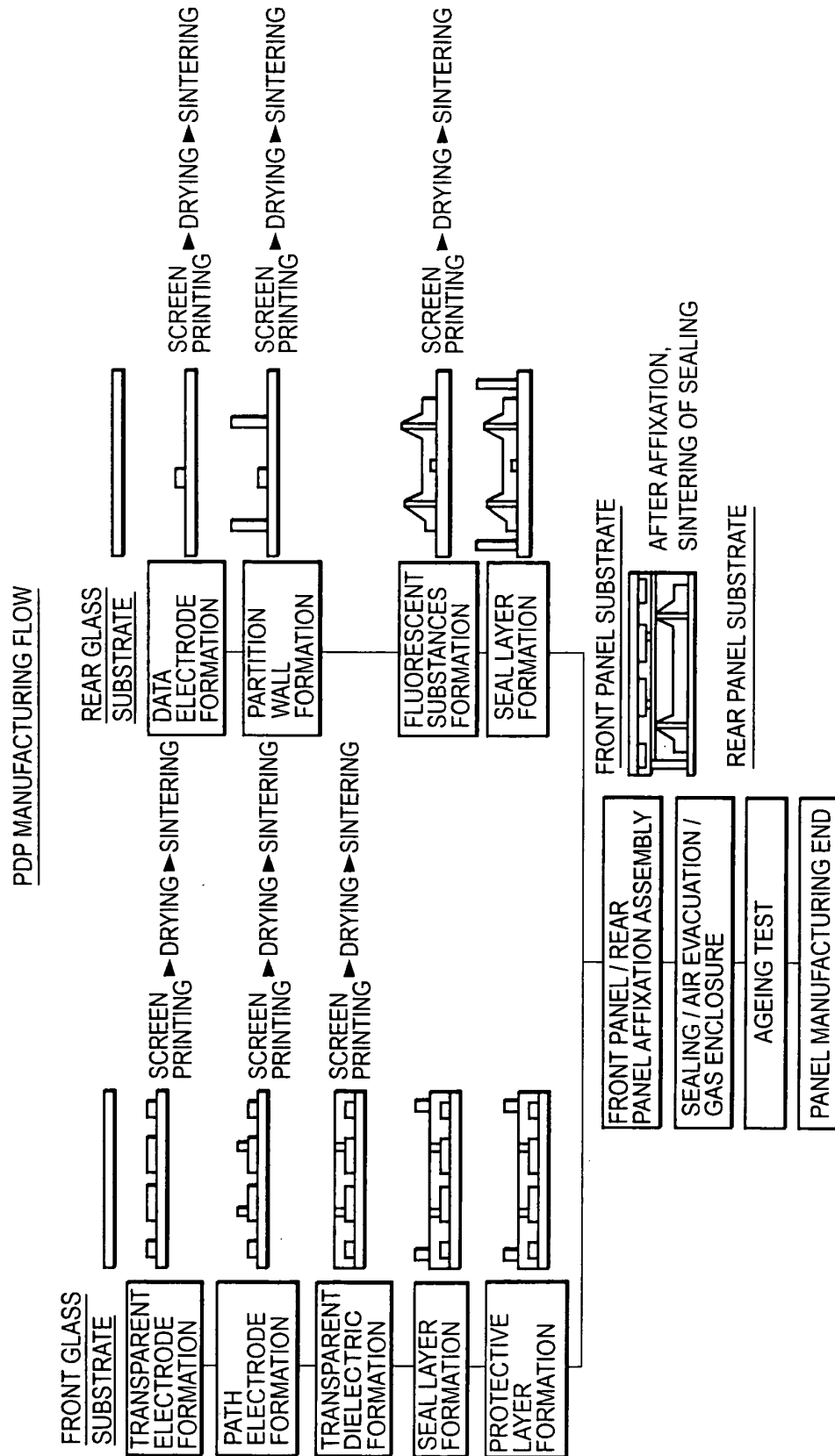


FIG. 4

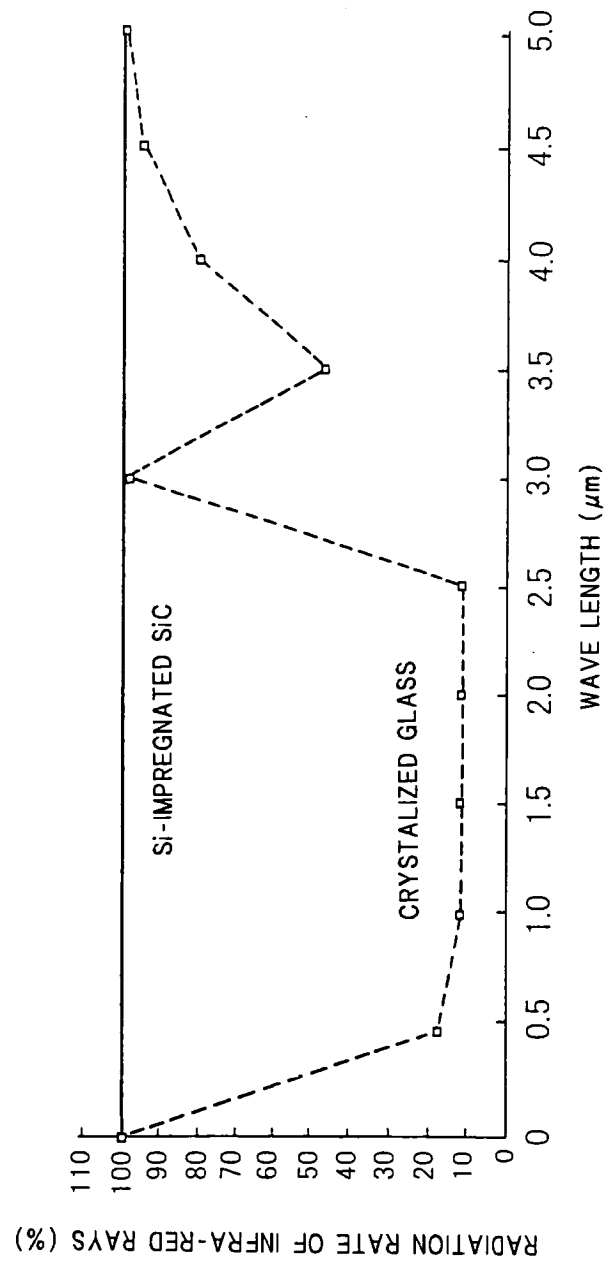


FIG. 5

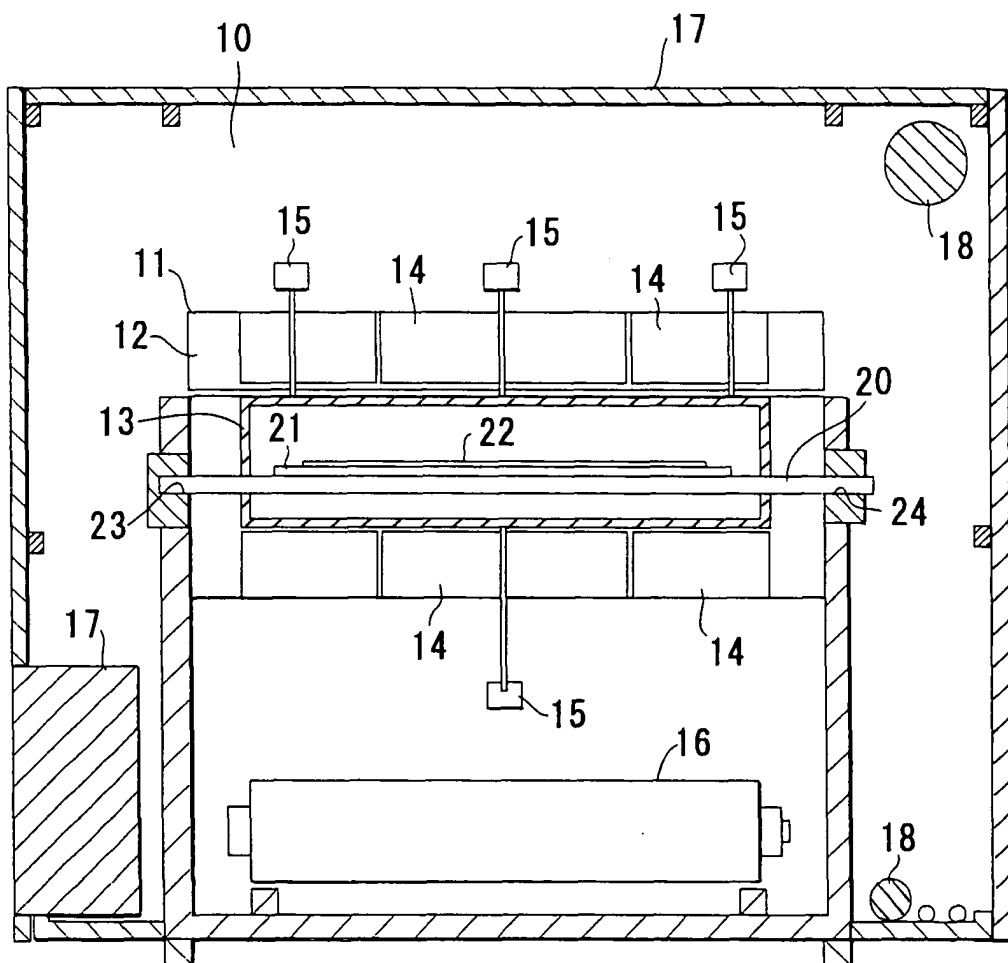


FIG. 6

