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TITLE OF THE INVENTION:

SUBSTRATE ASSEMBLING METHOD AND ASSEMBLING
APPARATUS

5 BACKGROUND OF THE INVENTION:

The present invention relates to a substrate assembling method intended for the assembly of liquid-crystal display panels in a vacuum environment, and to a substrate assembling apparatus.

10 The manufacture of liquid-crystal panels includes a process in which two glass substrates provided with circuit elements such as a transparent electrode and a thin-film transistor array, are to be assembled with an adhesive (hereinafter, this adhesive is also referred to as a
15 sealant) so that the clearance between these substrates will be about 2 μm in order to form a liquid-crystal charging space.

For example, Unexamined Japanese Patent Application Publication No. 2000-284295 describes a method in which
20 two substrates are to be assembled by applying pressure under the status that while one substrate, having a closed drawn pattern of sealant without a liquid-crystal charging port, is held on a table and then a liquid crystal is drip-applied to that substrate, the other substrate is
25 vacuum-attracted in absorbed the pressurizing plate

located on the above-mentioned table in a vacuum chamber and the distance between the table and the pressurizing plate is narrowed under the vacuum environment to pressurize the two substrates together.

5 In the case of the prior art described above, the flow of the gas released when the vacuum chamber is evacuated to achieve a vacuum status may abruptly move the substrates thus, disturbing the positioning thereof on the pressurizing plate and the table or even damage the
10 substrates. Also, since the substrates are abruptly depressurized, cells may be adversely affected by the atmosphere inside the vacuum chamber and by the moisture sticking to wall surfaces, substrate film surfaces, and liquid crystal surface.

15 In addition, although, in the case of the above-described prior art, the substrates are to be assembled by applying pressure to both substrates from the pressurizing plate, it may not be possible to laminate the upper and lower substrates into the desired clearance
20 merely by applying pressure from the pressurizing plate.

 Unexamined Japanese Patent Application Publication No. 2001-51284 describes a assembling apparatus that has a first pressurizing mechanism by which, during position matching of the upper and lower substrates by bonding,
25 pressure is to be applied to both substrates and then the

bottom of the upper substrate is to be brought into contact with the adhesive applied to the surface of the lower substrate, and a second pressurizing mechanism by which both substrates are to be assembled by the adhesive and
5 then a pressure different from that of the primary pressurizing mechanism is applied until the required clearance has been obtained, where the first and second pressurizing mechanisms operate in independent timing.

However, when the substrates to be assembled are very
10 large, it is difficult to pressurize the entire substrate evenly by means of the above-mentioned pressurizing mechanisms in the prior art, and in addition, there has been a need for the operator to adjust the respective pressures while closely watching the pressure status of
15 each end or corner of the substrates.

OBJECTS AND SUMMARY OF THE INVENTION:

The first object of the present invention is to supply, for the above reasons, a substrate assembling method for
20 assembling two substrates accurately, reliably, and within a short time even in the case of large substrates and a related assembling apparatus.

The second object of the present invention is to prevent the occurrence of the abrupt movement of the upper
25 and lower substrates and the freezing of moisture, by

controlling the speed of the release of air from the vacuum chamber in order to complete assembly reliably and within a short time.

According to the present invention, in order to fulfill
5 the above objects, the pressure applying mechanism consisting of a primary pressuring mechanism which applies pressure to the middles of substrates, and secondary pressuring mechanisms which applies pressure to the vicinity of the four corners of the rectangular substrates,
10 can be provided and after the middles and four corners of both substrates have been pressurized to the required pressure levels by use of the mechanism for pressurizing the middles of the substrates, and the mechanisms for pressurizing the corners thereof, respectively, the
15 clearance between the substrates or the diffusion status of an applied adhesive can be monitored and each mechanism for pressurizing the corner can be independently controlled according to monitoring results so that the substrates will be assembled with an even clearance over
20 the entire contact surface between the substrates.

In addition, it is possible to avoid the uncontrollable status of the substrates due to the flow of the air released and to prevent the freezing of moisture, by controlling the air release rate in order to evacuate the chamber from
25 its atmospheric pressure to the required low-pressure

status.

Furthermore, it is possible to provide the chamber with both gas induction piping and an air release valve and control the gas induction rate so that after assembly under
5 pressure, the rate at which the insufficiency of the clearance between the substrates is to be compensated for by returning the chamber to the original atmospheric pressure and a highly accurate assembling clearance can be obtained using the corresponding pressure change.

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BRIEF DESCRIPTION OF THE DRAWINGS:

FIG. 1 is a front view of an embodiment of the substrate assembling apparatus pertaining to the present invention.

FIG. 2 is a top view of the apparatus shown in FIG.

15 1.

FIG. 3 is a timing chart of each section of the apparatus when it laminates substrates under a depressurized status.

FIG. 4 is a view showing the unbalanced diffusion
20 status of the sealant between the substrates.

FIG. 5 is a view showing the adjustment method to be used in case of the imbalance shown in FIG. 4.

FIG. 6 is an example of the sealant coating form applied when the substrate assembling apparatus pertaining to the
25 present invention is used.

FIG. 7 is a side view of another embodiment of the present invention.

FIG. 8 is a view showing the apparatus configuration in which a gate valve is used as the air release valve.

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DESCRIPTION OF THE EMBODIMENTS OF THE INVENTION:

A schematic side view of an embodiment of the substrate assembling apparatus pertaining to the present invention is shown as FIG. 1. A top view of the substrate assembling apparatus in FIG. 1 is shown as FIG. 2.

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In FIG. 1, the substrate assembling apparatus comprises a stage section S1, a substrate assembling section S2, and a Z-axis movement stage S3. A base 2 for supporting the substrate assembling section S2 (chamber), and a base 3 for supporting the Z-axial movement stage S3 are provided above a base 1. Also, XYθ stage section S1 is provided on the surface of the base 1. In addition, control sections for the control of each stage section and of pressurizing mechanisms are provided (these control sections are not shown in the figure).

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During the operation of stage section S1, X-stage 4a can be moved in an X-axial direction, namely, horizontally on the drawing, by operating a driving motor 5 provided on a stage base 4d. There is a Y-stage 4b alive X-stage 4a, and the Y-stage can be moved in a Y-axial direction

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orthogonal to the X-stage by operating a driving motor 6. Also, a θ -stage 4c is present on Y-stage 4b and can be rotated horizontally with respect to Y-stage 4b via a rotary bearing 7 by operating a driving motor 8.

5 A lower table 9 for mounting one substrate 33 on θ -stage 4c is fixed to the upper end of a support column 10. Also, one end of bellows 12 is fixed to an arm 11 provided on Y-stage 4b. The other end of the bellows 12 is fixed to the members that form a depressurized chamber 15
10 (assembling chamber), and surrounds the support column 10. The arm 11 has a rotary bearing 13, support column 10 is installed so as to freely rotate by the rotary bearing 13 and a seal 14 with the respective central axes as the rotational center, and arm 11 is so constructed as not to
15 rotate together with support column 10.

Although this embodiment takes a configuration in which one support column 10 is provided in the center, the number of support columns 10 can be increased, provided that the required amount of rotation is possible.

20 Substrate assembling section S2 consists of a chamber 15 (assembling chamber); a table 9 provided inside the chamber 15; a pressurizing plate 16 provided above the table 9; a pair of substrate supporting claws for supporting an upper substrate 34 that comes off from the
25 pressurizing plate 16 when, as described later in this

document, the inside of chamber 15 is depressurized, and; a gate valve 17 provided at a first opening as a substrate entrance/exit portion on the side of chamber 15.

As described above, table 9 is fixed to the top of stage
5 section S1 via support column 10.

Pressuring plate 16 is fixed to the center guide plate 29 of Z-axial movement stage S3 via supports columns 27. Furthermore, each support column 27 is surrounded by bellows 28 one end of which is fixed to chamber 15 and the
10 other end of which is fixed to the center guide plate, and thus each support column 27 is constructed so that the internally depressurized status of chamber 15 can be maintained during the substrate assembly. In this embodiment, pressurizing plate 16 is fixed to the center
15 guide plate 29 via five support columns 27.

The inner bottom of chamber 15 is provided with first and second exhaust pipelines 20a and 20b for depressurizing the inside of chamber 15 and releasing its internal air. These exhaust pipelines 20a and 20b are connected to a
20 vacuum pump via a changeover valve not shown in the figure. The first exhaust pipeline 20a is smaller than the second exhaust pipelines 20b in terms of diameter, and for exhaust pipelines each having an approximately circular cross section, if the diameter of the first exhaust pipeline 20a
25 is taken as 1, that of the second exhaust pipeline 20b is

about 10 to 100 times as large. In this case, the diameter of the first exhaust pipeline 20a is set so as to achieve the exhaust rate at which, when the inside of chamber 15 is vacuum-exhausted, the flow of the gas does not allow
5 substrates 33 and 34 to move abruptly or permit the flyabout of the liquid crystal on lower substrate 33 or the release of pressure does not result in the freezing of moisture. For example, when the pipeline diameters are set, tests are conducted using pipelines of various diameters and the
10 diameter of the first exhaust pipeline 20a is determined from test results.

The internal pressure of chamber 15 during assembly is about 5×10^{-3} Torr.

In addition, the inner top of chamber 15 is provided
15 with a plurality of atmospheric shutoff windows 25 for observing the alignment position matchmarks provided on the substrates to be assembled. The amount of misalignment between the alignment position matchmarks on the upper and lower substrates is measured from the windows 25 by a
20 recognition camera 26 via the mark recognition holes (not shown in the figure) that are provided on pressurizing plate 16.

Furthermore, a pipeline 21 for returning the depressurized interior of chamber 15 to the original
25 atmospheric pressure is routed on the top of chamber 15.

A valve 22 for inducting a gas (air) into chamber 15 or for shutting off the gas (air) is provided in the middle of the pipeline 21. One end of this pipeline 21 has a connected pressure supply (for example, nitrogen gas tank)
5 not shown in the figure, and thus the rate of induction of the gas into chamber 15 can be controlled. This pressure supply does not always need to be provided.

Also, an air release valve 23 consisting of a plate-like body for closing the circular second opening
10 formed on one side of the chamber 15 (an opposite side of the gate valve 17 mentioned above). The inside of chamber 15 can be rapidly returned to the atmospheric pressure by distancing the air release valve 23 from the second opening. When the above-mentioned pipeline 21 has an approximately
15 circular cross section, it is preferable that the diameter of the second opening be at least 5 times of the diameter of the pipeline 21.

Table 9 is provided with an electrostatic chucking mechanism consisting of electrostatic chucking electrodes
20 for vacuum-attracting the lower substrate 33, and a suction chucking mechanism consisting of multiple suction chucking holes.

In this embodiment, these electrostatic chucking electrodes are almost rectangular flat-plate electrodes,
25 which are fit into two rectangular recesses formed at both

ends of table 9. Also, the electrostatic chucking electrodes have their surfaces (top of table 9) covered with a dielectric material, and this dielectric material is provided so that its principal plane is flush with the surface of table 9. The electrostatic chucking electrodes thus arranged on table 9 are connected to the respective positive or negative direct-current power supplies via switches as appropriate. Accordingly, when positive or negative voltages are applied to the electrostatic chucking electrode, a negative or positive charge will be induced on the principal plane of the dielectric material. And this charge will generate Coulomb force between lower substrate 33 and the transparent electrode film formed thereon, resulting in lower substrate 33 being electrostatically chucked to table 9. The voltages applied to the electrostatic chucking electrodes can be of mono-polar or same pole or different of bipolar.

Each chucking hole is connected to a vacuum pump via a chucking valve (not shown in the figure) provided outside chamber 15 via a pipeline 18. Bypass piping for releasing a vacuum into the atmosphere via a vacuum-breaking valve is provided in the middle of the pipeline 18. Chucked status can also be intentionally released by opening the vacuum-breaking valve.

Also, the inner end of chamber 15 that faces table 9

has a plurality vertical movement pins 35 for receiving lower substrate from a transfer machine (not shown in the figure), and then mounting the lower substrate on table 9 and for unloading assembled cells. These vertical movement pins 35 can move Z-axially in holes provided in table 9, and the movements are driven by a cylinder 36.

As with table 9, pressurizing plate 16 has an electrostatic chucking mechanism consisting of electrostatic chucking electrodes for chucking the upper substrate 34, and a suction chucking mechanism consisting of multiple suction chucking holes. Each suction chucking hole is connected to a vacuum pump via a chucking valve (not shown in the figure) provided outside chamber 15 via a pipeline 19.

In this embodiment, four pressurizing mechanisms 41 to 44 are provided overhanging above the surface of center guide plate 29 (above the support column 27), and one pressurizing mechanism 45 is provided almost in the center of the surface. Furthermore, center guide plate 29 has a mounted linear guide 30 that can be moved vertically with respect to base 3. The driving portion of each pressurizing mechanism is secured to the fixing support members 46a, 46b, 46c, 46d, and 47 that are provided on base 3.

This driving portion of each pressurizing mechanism

consists of motors equipped with encorder 41a, 42a, 43a, 44a, and 45a, and ball screws 41b, 42b, 43b, 44b, and 45b. Furthermore, loadcells 41c, 42c, 43c, 44c, and 45c for measuring pressure loads are provided at the working points
5 of force of each ball screw with respect to center guide plate 29.

Auxiliary member 48 for center guide plate 29 or for working out force thereon is provided with a linear guide 30 for Z-axial movement. This linear guide 30 can be moved
10 along a rail provided on base 3. When each pressurizing mechanism is activated to move center guide plate 29 downward, pressurizing plate 16 fixed to support column 27 will be pushed downward, with the result that upper substrate 34 chucked to pressurizing plate 16 will be
15 pressed down against lower substrate 33.

Although, in this embodiment, five pressurizing mechanisms are provided, these can be replaced with four such mechanisms by which the equal force is exerted on the four corners of the rectangular substrate. Although this
20 embodiment employs a configuration in which force is applied to pressurizing plate 16 via center guide plate 29, the pressurizing mechanisms can also be constructed so as to apply force directly on pressurizing plate 16. In this case, although center guide plate 29 becomes
25 unnecessary and the number of apparatus components

required correspondingly decreases, the mechanism for maintaining the degree of internal depressurization of chamber 15, and disassembly performance for the maintenance of the apparatus is slightly inferior.

5 Next, the assembly work of liquid-crystal panel-use substrates by the use of the substrate assembling apparatus of the above-described configuration is described below.

 To assemble liquid-crystal panel-use substrates, the upper substrate 34 or lower substrate 33 requires endless
10 line pattern with an adhesive to form a frame on either substrate. An example of forming this frame is shown in FIG. 6. And in this embodiment, the required amount of liquid crystal is drip-applied to the lower substrate 33 as the substrate on which the frame has been formed. Before
15 the drip-application of the liquid crystal or before substrate assembly following the drip-application, spacers for determining the required substrate-to-substrate clearance are placed across the surface of the lower substrate 33 or upper substrate 34. These spacers
20 can also be included in the liquid crystal. Although, in this embodiment, an adhesive is applied to lower substrate 33, the adhesive can be applied to upper substrate 34 instead. In the latter case, however, the liquid-crystal drip-application area on lower substrate 33 needs to be
25 the area surrounded by adhesive provided on upper substrate

34.

First, upper substrate is mounted on the transfer machine (not shown in the figure) that is located outside chamber 15 with its film surface faces downward, and the peripheral fringes of the upper substrate are suction-chucked from bottom by operating the hand of the transfer machine. Next, gate valve 17 at the first opening of chamber 15 is opened and after the hand of the transfer machine has been inserted into the chamber, pressurizing plate 16 is pressed against upper substrate 34. And upper substrate 34 is chucked to pressurizing plate 16 by suction-chucking the upper substrate by use of the suction chucking holes in the suction chucking mechanism provided at pressurizing plate 16. After upper substrate 34 has been chucked to pressurizing plate 16, the suction force of the hand of the transfer machine is cut off. After this, the hand is moved away from the inside of chamber 15. Although it has been described that the hand of the transfer machine has a suction chucking function, upper substrate 34 can also be inserted into the chamber just by using the claw mechanism for supporting the upper substrate.

Next, vertical movement pins 35 provided on the table 9 within chamber 15 are moved upward so that the top end of each pin protrudes above table 9. And after the hand of the transfer machine has been operated to support lower

substrate 33 so that its liquid-crystal drip-applied side facing upward, the lower substrate is inserted into chamber 15 and transferred onto vertical movement pins 35. After the transfer, the hand of the transfer machine is moved
5 away from the inside of chamber 15. After the hand has been moved away, gate valve 17 is closed and then vertical movement pins 35 are moved downward to transfer lower substrate 33 onto table 9. After lower substrate 33 has been transferred onto table 9, the lower substrate is
10 suction-chucked using the suction chucking holes of table 9.

After lower substrate 33 and upper substrate 34 have been secured to table 9 and pressurizing plate 16, respectively, by suction chucking, the valve provided on
15 the first exhaust pipeline 20a is first opened to release the internal gas of chamber 15 gradually. The exhaust rate at this time is set so that neither the uncontrollable status of the substrates or the flyabout of the liquid crystal on lower substrate 33 is brought about by the flow
20 of the gas nor the freezing of moisture is caused by depressurization. During gradual release of air from the inside of chamber 15, when the uncontrollable status of the substrates or the flyabout of the liquid crystal are not caused by any increases in the exhaust rate and when
25 pressure is reduced to a level at which no moisture is frozen

by the depressurization (for example, when the upper substrate 34 that has been chucked to the pressurizing plate by vacuum attraction force is depressurized to such an extent that the substrate does not leave the pressurizing plate), the valve on the first exhaust pipeline 20a is closed. And the valve on the second exhaust pipeline 20b is opened and depressurization rapidly occurs to achieve the pressure of (5×10^{-3} Torr) required for the assembly of the upper and lower substrates.

When, as described above, the inside of chamber 15 is depressurized, the internal atmospheric pressure of chamber 15 decreases below the chucking force of upper substrate 34 and as a result, the upper substrate may leave pressurizing plate 16. For this reason, substrate supporting claws 40 are provided at the inner end of chamber 15 that faces pressurizing plate 16. If decreases in the internal atmospheric pressure of chamber 15 cause upper substrate 34 to leave pressurizing plate 16, the upper substrate will be supported by substrate supporting claws 40. Substrate supporting claws 40 are constructed so that when the substrates are suction-chucked or when they are mechanically pressurized by pressurizing plate 16, the substrate supporting claws can be moved away to avoid contact with the edges of the substrates.

The process in which the substrates 33 and 34 that have

been supported on table 9 and pressurizing plate 16 are to be assembled as described above is described in further detail below using FIG. 3. A timing chart covering the internal depressurization of chamber 15, action of suction force, driving status of each motor, and positioning operation that exist from substrate supporting to substrate assembly by mechanical pressurization, followed by the release of air, is shown as FIG. 3.

First, upper substrate 34 is chucked to pressurizing plate 16 by suction chucking at time t_1 as shown in FIG. 3. After this, lower substrate 33 is also transferred onto the table 9 within chamber 15 and suction-chucked onto table 9. Next, the internal depressurization of chamber 15 is started at time t_2 . At time t_3 during the depressurization, the internal pressure of chamber 15 decreases below the suction chucking force applied to the upper substrate 34 which has been supported by pressurizing plate 16 by use of suction chucking, and as a result, upper substrate 34 may not be capable of being suction-chucked, resulting in dropping onto substrate supporting claws 40. If this happens, upper substrate 34 will be re-chucked to pressurizing plate 16 by energizing the electrostatic chucking electrode at the time (t_4) the required vacuum-pressure is attained. The required vacuum-pressure here refers to a status under which a discharge

does not occur between the electrodes on the electrostatic chucking plate. Even when upper substrate 34 does not drop, if the required vacuum-pressure is attained, upper substrate 34 will be electrostatically chucked.

5 The reasons why suction chucking and electrostatic chucking are combined in this embodiment as described above are shown below. To maintain the chucking of upper substrate 34 to pressurizing plate 16 just by suction chucking, the upper substrate needs to be suction-chucked
10 with suction force greater than the degree of internal depressurization of chamber 15, and it also requires a vacuum pump having a greater capacity. In addition, when upper substrate 34 is electrostatically chucked in the atmosphere and depressurization takes place under this
15 state, since the air left between upper substrate 34 and pressurizing plate 16 will expand and be released, there will be partial clearances between upper substrate 34 and pressurizing plate 16. Consequently, a discharge will occur between the positive and negative electrodes
20 provided on pressurizing plate 16, resulting in damage to upper substrate 34 and pressurizing plate 16. Also, since the discharge will reduce electrostatic chucking force, the resulting drop of upper substrate 34 may cause a further discharge to occur with a certain clearance at that moment.
25 This discharge in a vacuum occurs under the relationship

between the amount of voltage, pressure, and an
electrode-to-electrode clearance, pursuant to the
Paschen's law. For this reason, electrostatic chucking of
upper substrate 34 to pressurizing plate 16 in the
5 atmosphere permits air to flow out during depressurization
as described above, with the result that the above-
mentioned discharge phenomenon occurs.

In this embodiment, therefore, prior to electrostatic
chucking, pressure is reduced to such an extent that no
10 such discharge phenomenon occurs. Hereby, it becomes
possible not only to achieve compact apparatus design, but
also to chuck and hold the substrates to pressurizing plate
16 and table 9 reliably and completely. Although, in the
timing chart of FIG. 3, electrostatic chucking is
15 accomplished by applying a voltage to the electrostatic
chucking electrodes of table 9 and pressurizing plate 16
before depressurization is completed (that is to say, at
time t_4), electrostatic chucking can also be provided after
depressurization.

20 After both lower substrate 33 and upper substrate 34
have been fixed to table 9 and pressurizing plate 16 by
electrostatic chucking as described above, adjustments are
performed for pressurizing plate 16 to become parallel to
table 9. After this, upper substrate 34 is brought close
25 to lower substrate 33 by the collaborative operation of

the motors of each pressurizing mechanism so as to ensure that the center guide plate 29 of Z-axial movement stage section S3 moves downward. First, before upper substrate 34 is brought into contact with the adhesive provided on lower substrate 33, the position alignment matchmarks provided on the upper and lower substrates are detected using recognition camera 26 and then the amount of position mismatching between both substrates is measured. Next, table 9 with lower substrate 33 mounted thereon is moved by the control of stage S1, based on the measured value, and the position of lower substrate 33 is matched to that of upper substrate 34.

After position matching, the adhesive that has been applied to lower substrate 33 is diffused by moving the center guide plate 29 further downward, and then primary assembly (primary pressurization) is conducted with the liquid crystal charged into the frame which has been formed by the diffusion of the adhesive. During primary assembly, immediately after upper substrate 34 has come into contact with the adhesive, position matching is accomplished again by use of the camera. The position matching operation in this case is repeated several times until the maximum permissible pressure has been applied. The position matching operation is repeated to compensate for the possible misalignment between the substrates due to the

shear force which may be exerted between both substrates if, in case of nonuniform coating with the adhesive, even the uniform application of the pressure does not diffuse the adhesive uniformly and this, in turn, results in force
5 not being uniformly applied to the adhesive.

After primary assembly (primary pressurization), the voltage that has been applied to the electrostatic chucking electrode of pressurizing plate 16 is cut off and then the application of suction chucking force is also discontinued.
10 And the pressurizing mechanism is operated to move pressurizing plate 16 upward. After this, a gas is charged into chamber 15 from pipeline 21 to return the internal pressure of chamber 15 to the original atmospheric pressure.

15 At this time, since pressurizing plate 16 is not easy to make strictly parallel to the surface of table 9 during assembly, if the adhesive is diffused nonuniformly during the assembly or by the possible deformation of the substrates themselves, the clearance between the assembled
20 substrates may not be uniform. Therefore, before pressurizing plate 16 is moved upward as described above, the amounts of diffusion of the adhesive on each side of the substrates are monitored. And for a side small in the amount of diffusion of the adhesive, of all pressurizing
25 mechanisms arranged on the periphery (at four corners),

only the pressurizing mechanism corresponding to that side is increased in terms of pressurizing force and the pressurizing mechanism corresponding to the opposite side is reduced in terms of pressurizing force. Adjustments are performed in this way so that the adhesive is diffused equally on each side of the substrates.

Although, in the above description, the amounts of diffusion of the adhesive are monitored inside depressurized chamber 15, the monitoring operations can also be performed after the inside of chamber 15 has been returned to the atmospheric pressure. Or the pressurizing force of each pressurizing mechanism can also be set to the respective appropriate value for uniform diffusion of the adhesive by assembling several substrates.

An example of the unbalanced diffusion status of adhesive 37 is shown as FIG. 4. The clearance adjustment method to be used under the status of FIG. 4 is shown in FIG. 5.

As shown in FIG. 4, if the amount of diffusion of adhesive 37 is too great on the left side and too small on the right side, each pressurizing mechanism is to be actuated in the direction of the arrow by, as shown in FIG. 5, reducing the pressurizing force of pressurizing mechanisms 41 and 42 and increasing that of pressurizing mechanism 43 and 44. At this time, the center portion is

to be maintained in its current status. It is possible by performing the above operations to remove the nonuniformity of the clearance between substrates due to the deformation of the substrates or inappropriate application of adhesive 37. Also, in this embodiment, each pressurizing mechanism is so constructed as to be independently driven to ensure independent pressurization of the substrate peripheries. Although the amounts of diffusion of adhesive 37 can be visually monitored, these amounts of diffusion can also be monitored using other methods. For example, measurement with optics such as a camera, or detection with a clearance sensor is possible.

At this phase, for a small panel size, the desired pressure can be applied using such mechanical pressurizing mechanisms as mentioned above. For a large panel size, however, to obtain the required substrate-to-substrate clearance with a mechanical pressure, it is necessary to increase the size of the pressuring units themselves so that a greater pressure can be applied. To maintain the size of the pressuring units at its current value, the adoption of other pressurizing means need to be considered. By the way, when the internal status of substrates is changed from the required depressurized status to an atmospheric pressure, a great pressure can be applied to the entire substrates since they are internally

depressurized. For example, the application of an atmospheric pressure to the surfaces of substrates whose interior is maintained under the required depressurized status (for example, 5×10^{-3} Torr) enables force of 121.6 kN to be applied.

The substrate-to-substrate clearance existing when the maximum permissible pressure is applied mechanically via pressurizing plate 16 in the case of the current pressurizing mechanisms is about $15 \mu\text{m}$ and the bonded status at this time is not perfect. In other words, under the status of primary pressurization (pre-pressurization), since the desired clearance is not yet achieved, the diffusion of the adhesive is not sufficient and its contact portion with respect to the upper and lower substrates is short. In addition, since the liquid crystal with which the cell has been charged is not diffused inside it and thus a large vacuum space is generated between the liquid-crystal charged surfaces, further pressurizing is needed for the substrate-to-substrate clearance (determined by the sizes of spacers) to be reduced below the appropriate value of $5 \mu\text{m}$ (preferably, $4 \mu\text{m}$).

In order to execute secondary pressurization of the substrates (namely, pressurization by the reversion of the chamber interior to the atmospheric pressure), since the inside of the cell between the substrates is maintained

under an almost vacuum status, the entire substrate surface can be pressurized almost uniformly by returning the periphery of the cell to the atmospheric pressure. If the periphery is abruptly returned to the atmospheric pressure, however, since the diffusion of adhesive 37 is not yet sufficient, the gas will break adhesive 37 and enter the internal vacuum space of the cell, with the result that the liquid-crystal substrates will be defective products. In this embodiment, therefore, after pressurization by pressurizing plate 16, the pressurizing plate is moved away from the surface of upper substrate 34 and then the valve 22 on pipeline 21 is opened so that the gas that has been pressurized by a pressure supply is inducted into chamber 15 for its gradual return to the atmospheric pressure. At the same time, uniform distribution of the gas inside chamber 15 (uniform distribution of pressure) can also be realized by inducting air (or a gas such as a nitrogen gas) into chamber 15 by use of the suction chucking holes provided in pressurizing plate 16 and table 9. When the inside of chamber 15 is gradually returned to the atmospheric pressure in this way, the cell will be gradually pressurized and adhesive 37 will be progressively diffused. Since there will be gradual increases in the difference between the pressure of the depressurized internal space of the cell and the pressure

inside chamber 15, the inducted gas will neither break the adhesive nor enter the cell, with the result that the contact area of the adhesive with respect to the upper and lower substrates will gradually increase.

5 Also, when the clearance between the substrates becomes about 10 μm , the flow of the adhesive will be induced by the start of its diffusion and the viscosity of the adhesive will decrease because of its thixotropy. After the viscosity of the adhesive has decreased, a high
10 pressure can be applied to the substrate by opening the air release valve 23 that rapidly returns the inside of chamber 15 to the atmospheric pressure. At the time of the pressurization, since the adhesive has already spread over the entire substrate and improved in sealing performance,
15 the gas will neither break the adhesive nor enter the cell. In addition, the substrate assembling time is reduced because the adhesive has already decreased in viscosity and is therefore diffused rapidly and thus because the liquid crystal is also diffused by the pressurization. In
20 this mode of embodiment, air release valve 23 will be opened when the pressure gauge provided on chamber 15 detects a value exceeding the required pressure.

 Also, cylinder 24 for operating air release valve 23 is so set as to operate when the internal pressure of chamber
25 15 becomes an atmospheric pressure. Thus, when the

internal pressure of chamber 15 arrives at the required value, even if the operator forgets closing the valve 22 that gradually returns the inside of chamber 15 to the atmospheric pressure, air release valve 23 will be
5 automatically opened so that the internal pressure of chamber 15 can be prevented from exceeding the original atmospheric pressure to ensure safety for the operator. In short, air release valve 23 can be operated as a safety valve.

10 In this way, the assembling operation in this embodiment is accomplished. During the process in this embodiment, the pressurizing mechanism for applying pressure to the center of the pressurizing plate, and the four pressurizing mechanisms for applying pressure to
15 periphery are operated at the same time. Incidentally, after pressurizing the center pressurizing mechanism in order to avoid nonuniform distribution of pressure to the substrate, caused by events such as the deformation of that substrate, or unbalanced diffusion of the adhesive, caused
20 by the unbalanced application thereof, uniform diffusion of the adhesive can likewise be achieved by monitoring the diffusion status of the adhesive and independently operating each pressurizing mechanism arranged at each corner, instead of operating all five pressurizing
25 mechanisms at the same time.

Or after, instead of providing the center pressurizing mechanism, arranging a set of pressurizing mechanisms for applying pressure to the vicinity of each corner (rectangular side) of the rectangular substrate and
5 applying pressure by providing collaborative control of the four pressurizing mechanisms, uniform diffusion of the adhesive can likewise be achieved by monitoring the diffusion status of the adhesive and independently driving the four pressurizing mechanisms according to the
10 monitored diffusion status of the adhesive.

Next, another embodiment of the present invention is described below. A side view of the substrate assembling apparatus pertaining to another embodiment is shown as FIG. 7.

15 This second embodiment differs from the above-described first embodiment in that when center guide plate 29 is depressed by center pressurizing mechanism 45, the four pressurizing mechanisms provided around the substrates will move downward with center guide plate 29.
20 That is to say, the four pressurizing mechanisms, 41 to 44, are fixed to the guide member 55 of each pressurizing mechanism so that the pressurizing mechanisms move together with center guide plate 29. And when force is to be exerted on center guide plate 29 from the four
25 pressurizing mechanisms, the clearances between

pressurizing mechanism guide members 55 and center guide plate 29 can be varied by driving the respective ball screws. Although such independent operation of the four pressurizing mechanisms with respect to the operation of the center pressurizing mechanism makes the configuration of the apparatus slightly complex, control is simplified and working time can be reduced.

The liquid-crystal substrates used in this embodiment are large-size substrates intended for multiple-product processing. In this embodiment, therefore, by providing, as shown in FIG. 6, a dummy seal 39 around the plurality of seals 37 constituting each liquid-crystal substrate, the entire surface of the substrate constituted by the seals can be made to undergo uniform pressure distribution by the depressurization of the seals and dummy seal constituting the liquid-crystal substrate, and the use of this apparatus enables the formation of liquid-crystal panels with an even more accurate substrate-to-substrate clearance.

Next, an example of the pressure change for returning the inside of chamber 15 to the original atmospheric pressure during secondary pressurization is described below.

First, the cylinder 24 for opening and closing air release valve 23 is set to valve-closing force beforehand

until the required pressure greater than the atmospheric pressure has been reached. Next, the valve 22 provided on pipeline 21 is opened, which then drives the pressure supply connected to pipeline 21 and inducts a gas into
5 chamber 15 gradually. When the internal pressure of chamber 15 is increased above the atmospheric pressure (in other words, when the pressure that has been set for cylinder 24 is exceeded), air release valve 23 will operate to return the inside of chamber 15 to the atmospheric
10 pressure. The adoption of this configuration enables the force required for sufficient substrate assembly to be equally applied by adjusting the preset force of cylinder 24, even when the substrates to be assembled are very large and require great pressurizing fore.

15 After, in this way, the substrates have been assembled and the inside of chamber 15 has been returned to the atmospheric pressure, the valve 22 for the gradual return to the atmospheric pressure is closed and then gate valve 17 is opened. Next, the applied voltage of the
20 electrostatic chucking electrode on table 9 is cut off and furthermore, the suction force of the suction chucking holes is reduced to zero. After this, the top ends of vertical movement pins 35 are protruded above the surface of table 9 to move the assembled substrates upward. Under
25 this state, the hand of the transfer machine is operated

so as to adjust the assembled substrates to a height at which they can be removed. After the adjustment, the substrates are inserted into chamber 15, then transferred onto the hand of the transfer machine, and unloaded from
5 the chamber.

Although it is described in the above embodiment that air release valve 23 is provided separately from the gate valve 17 intended to load and unload substrates, the air release valve can also be operated as gate valve 17. The
10 configuration of the gate valve which combines gate valve and air release valve functions is shown in FIG. 8.

Gate 61 has a connected shaft 62. Shaft 62 can be moved horizontally via a linear guide 63. Gate 61 can be separated from chamber 15 by operating a cylinder 64.
15 Linear guide 63 and cylinder 64 are fixed to an arm 65, which is connected to a cylinder 66 intended to move gate 61 vertically.

When the internal pressure of chamber 15 is to be returned to the atmospheric pressure rapidly, gate 61 is
20 separated from chamber 15 by cylinder 64 and as a result, gate 61 is opened to induct air into chamber 15.

The adoption of such configuration with a gate valve also functioning as the valve for a rapid return to atmospheric pressure reduces the number of apparatus
25 components required and enables easy assembly.

The use of the above-described assembling apparatus and assembling method pertaining to the present invention enables reliable, accurate, short-time, and safe assembly of two substrates, especially, liquid-crystal substrates.

WHAT IS CLAIMED IS:

1. A substrate assembling apparatus equipped with
a table on which one substrate is to be mounted thereon,
5 and with a pressurizing plate that supports another
substrate facing it towards said substrate with a clearance,
and designed so as to apply an adhesive to at least either
one substrate, then match this substrate and the other
substrate in terms of position inside a depressurized
10 chamber, and laminate both substrates by driving a set of
pressurizing mechanisms for mechanically applying
pressure to the above-mentioned other substrate, wherein
said substrate assembling apparatus is characterized in
that four pressurizing mechanisms so arranged as to enable
15 independent application of pressure to the vicinity of
positions equivalent to the four corners of said substrate,
and a sensor for monitoring the substrate assembly status
created using said four pressurizing mechanisms are
provided, in that said four pressurizing mechanisms are
20 operated until the required pressure has been reached, and
in that a control section is equipped that variably
controls the pressurizing force of the four pressurizing
mechanisms according to the substrate assembly status
which has been monitored by said sensor.

2. A substrate assembling apparatus as set forth in Claim 1 above, wherein the substrate assembling apparatus is characterized in that in addition to said four pressurizing mechanisms, a fifth pressurizing mechanism
5 for applying pressure to the center of the substrate is provided and in that after said five pressurizing mechanisms have been operated, the pressurizing force of the first four pressurizing mechanisms arranged near the four corners of said substrate is variably controlled
10 according to the particular assembly status of both substrates.

3. A substrate assembling apparatus as set forth in Claim 2 above, wherein the substrate assembling apparatus
15 is characterized in that a suction chucking mechanism for providing suction chucking to said pressurizing plate, and an electrostatic chucking mechanism for chucking by use of electrostatic force are provided, in that said suction chucking mechanism is operated until said chamber has been
20 changed from its atmospheric status to the required depressurized status, and in that said electrostatic chucking mechanism is operated until assembly has been accomplished by providing mechanical pressurization from the required depressurized status of the chamber.

4. A substrate assembling apparatus as set forth in Claim 3 above, wherein the substrate assembling apparatus is characterized in that after completion of mechanical pre-pressurization inside the depressurized chamber, the
5 required substrate-to-substrate clearance can be obtained by applying an atmospheric pressure to the required substrate as the main pressurization.

5. A substrate assembling apparatus as set forth in
10 Claim 1 above, wherein the substrate assembling apparatus is characterized in that it has a gas release means for depressurizing the inside of said chamber, and a means for activating said gas release means so as to make the gas release rate variable.

15

6. A substrate assembling apparatus as set forth in Claim 5 above, wherein the substrate assembling apparatus is characterized in that said gas release means comprises a thin pipeline for gradually releasing the gas, a thick
20 pipeline for rapidly releasing the gas, and a solenoid valve for selecting one of said two pipelines connected to a vacuum-pressure supply.

7. A substrate assembling apparatus as set forth in
25 Claim 1 above, wherein the substrate assembling apparatus

is equipped with a gas inducting pipeline which is valved thereon and connected to a pressure supply to induct a gas into said chamber gradually, and with an air release valve for rapidly changing the inside of the chamber to an
5 atmospheric pressure.

8. A substrate assembling apparatus as set forth in Claim 7 above, wherein the substrate assembling apparatus is characterized in that it applies the required
10 pressure to said air release valve and in that when the internal pressure of the chamber exceeds the required pressure mentioned above, the air release valve will be opened.

15 9. A substrate assembling method characterized in that the assembly of two substrates with an almost uniform clearance between them can be accomplished inside a vacuum chamber by, after either one of two substrates has been annularly coated with an adhesive and a liquid crystal has
20 been drip-applied to the annularly coated surface, fixing that substrate to the surface of a table with the liquid-crystal surface facing upward, chucking the other substrate to a pressurizing plate, position-matching this upper substrate to the above-mentioned lower substrate,
25 assembling the upper and lower substrates at the required

pressure by operating a pressurizing mechanism provided
in the center of said pressurizing plate, measuring the
clearance between the assembled substrates, and
independently operating four pressurizing mechanisms for
5 applying pressure to the vicinity of the four corners of
the pressurizing plate.

10. A substrate assembling method as set forth in
Claim 9 above, wherein the assembling method is
10 characterized in that the assembly of two substrates with
an almost uniform clearance between them can be
accomplished by operating said electrostatic chucking
mechanism after the required depressurized status has been
obtained, chucking the other substrate properly to the
15 pressurizing plate, position-matching both upper
substrate and lower substrate under this state, conducting
the pressure-assembly by means of five pressurizing
mechanisms intended to apply pressure to the center of the
pressurizing plate and the vicinity of the four corners
20 thereof, monitoring the clearance between the substrates,
and variably controlling the pressurizing force of the
pressurizing mechanisms near said four corners according
to the monitored clearance between the substrates.

25 11. A substrate assembling method as set forth in

Claim 9 above, wherein the assembling method is characterized in that position matching between two substrates can be accomplished by operating said electrostatic chucking mechanism after the required
5 depressurized status has been obtained, chucking the other substrate to the pressurizing plate, position-matching both upper substrate and lower substrate under this state, gradually increasing pressures by means of five pressurizing mechanisms intended to apply pressure to the
10 center of the pressurizing plate and the vicinity of the four corners thereof, monitoring the clearance between the substrates, and repeatedly monitoring the clearance between the substrates several times before the maximum permissible pressurizing force is reached.