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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 method and apparatus for assembling a pair of substrates as components of a liquid crystal display panel in a depressurized state. More particularly, it relates to a method for assembling
10 substrates which can be effectively used to prevent nonconforming liquid crystal display panels to be produced.

To manufacture a liquid crystal panel, two glass substrates with a transparent electrode and thin film transistor array mounted thereon are bonded together on
15 the periphery of the substrate using an adhesive (hereinafter referred to as "sealing agent") provided in a square form, for example, at a very close interval of 2 microns (the substrate subsequent to bonding is
20 hereinafter referred to as "cell"), and the liquid crystal is sealed in a space between each substrate and adhesive.

A substrate bonding method for sealing the liquid crystal is disclosed in the Official Gazette of Japanese Application Patent Laid-Open Publication No. Hei 12-284295.
25 According to this method, liquid crystal is dripped on one

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of the substrates written on the pattern (in a square form) with sealing agent closed therein so that the inlet is not provided. The other substrate is laid above the first substrate in a vacuum chamber. In the vacuum state, the space between these two substrates is reduced to increase the pressure, whereby upper and lower substrates are bonded together. Another method is disclosed in the Japanese Application Patent Laid-Open Publication No. Hei 10-177178 wherein, to harden the adhesive (sealing agent) in bonding the substrates together, the sealing agent coated on the substrates is hardened by irradiation energy on the temporary basis. Then liquid crystal is dripped on the substrates, thereby allowing them to be bonded together. After that, the sealing agent is hardened by the irradiation energy different from the last irradiated one,

In recent years, a liquid crystal display panel has been growing in size, and there has appeared a substrate having one side exceeding 1000 mm, and a thickness of 0.7mm. Incidentally, it has been proven by experiment and computer analysis that, when both ends of such a large substrate are raised, deflection of about 80 to 100 mm will occur. So the cell comprising two large-sized substrates bonded with each other is also deflected under its own weight during the travel, and compressive force, for example, is applied to the sealed surface of the lower substrate, while

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tensile stress is applied to the sealed surface of the upper substrate. Accordingly, misalignment occurs between the upper and lower substrate, with the result that sealed portion is damaged and the liquid crystal is discharged.

5 Such large-sized substrates are provided with continuous seal patterns having no multiple breaks thereon, and each pattern is filled with liquid crystal so that multiple liquid crystal display panels are formed. Such a multiple pattern method is used in some cases. To bond
10 two substrates together in such a case, pressure is applied to two substrates which are in the depressurized state, as disclosed in the above-mentioned Japanese Application Patent Laid-Open Publication No. Hei 12-284295. When atmospheric pressure is regained in a vacuum chamber, the
15 pressure applied to the substrates is used. In the case of the above-mentioned large-sized substrates, however, uniform pressure is not applied when the atmospheric pressure is to be regained. An adequate gap cannot be obtained between substrates. This problem has been found
20 out in the prior art. To solve this problem, namely, to ensure uniform pressure to be applied, it is possible to use a method for provide another dummy seal pattern, in addition to the seal pattern for filling liquid crystal comprising sealing agent. It is also possible to dot-coat
25 the ultraviolet curing close to this dummy seal pattern,

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and to apply ultraviolet rays from outside the vacuum chamber, thereby allowing the ultraviolet curing agent to be hardened so that temporary securing is provided.

If these methods are used, however, pressure
5 difference occurs between the inside and outside of the dummy seal, when the pressure the cells bonded together under vacuum is put back to the atmospheric pressure. Without the dot-coated ultraviolet curing agent being collapsed, its height exceeds that of the sealing agent.
10 This leads to faulty gap between the substrates close to the ultraviolet curing agent, with the result that uneven color subsequent to lighting occurs, according to the above-mentioned prior art.

15 SUMMARY OF THE INVENTION:

The object of the present invention is to solve the above-mentioned problems of the prior art and to provide a substrate assembling method and apparatus which ensure a desired gap even at a position close to ultraviolet curing
20 agent, without any displacement of the upper and lower substrates during cell transport, whereby occurrence of a nonconforming cell product can be avoided.

To achieve the above-mentioned object, the present invention adopts a temporary securing mechanism wherein,
25 after two substrates placed at closer intervals with each

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other are subjected to primary pressurization in the vacuum chamber under a depressurized state, curing agent for temporary securing provided at multiple positions on one of the substrate is hardened by application of ultraviolet rays while pressure is applied in the vacuum chamber under a depressurized state. For example, the aforementioned temporary securing mechanism is composed of bundles of ultraviolet fiber elements arranged in a hollow cylindrical pressure bar in a state vacuum-isolated by means of a material transmissive to ultraviolet rays, and is capable of moving in the vertical direction in the vacuum chamber with the depressurized state in the vacuum chamber kept unchanged.

In the present invention, the aforementioned step of primary pressurization, the temporary securing is followed by the step of hardening the adhesive for temporary securing in each substrate passing through the process of primary pressurization by application of both ultraviolet rays and pressure. In this step of temporary securing, for example, a predetermined pressure is applied to the tip of the aforementioned hollow cylindrical pressure bar where the adhesive for temporary securing in the substrate is provided, and the space between substrates at the pressurized portion is determined as a final gap. After that, ultraviolet rays are applied to the adhesive for

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temporary securing sandwiched between substrates to promote hardening. This allows the portion provided with temporary securing adhesive as an independent portion to be the final gap, with the result that temporary securing can be achieved in such a position. The present invention provides the secondary pressurization step wherein atmospheric pressure is regained in the vacuum chamber after the process of temporary securing, whereby pressure is applied to bond the substrates together.

BRIEF DESCRIPTION OF THE DRAWINGS:

Fig. 1 is a schematic side view showing the configuration of a substrate bonding apparatus as a first embodiment of the present invention;

Fig. 2 is a cross sectional view representing the configuration of the temporary securing mechanism according to the present embodiment;

Fig. 3 is a top view illustrating the position of coating the substrate with ultraviolet curing agent, namely, the position of the temporary securing mechanism with respect to the substrate, according to the present embodiment;

Fig. 4 is a side view representing an example of the state of a pair of substrates subsequent to the primary pressurization according to the present embodiment;

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Fig. 5 is a side view representing an example of the state of a pair of substrates at the time of temporary securing according to the present embodiment;

5 Fig. 6 is a side view representing the secondary embodiment of the substrate bonding apparatus of the present invention, and illustrating the layout position of the temporary securing mechanism according to the present embodiment;

10 Fig. 7 is a drawing illustrating an embodiment of the configuration of an electrostatic chuck;

Fig. 8 is a drawing illustrating another embodiment of the configuration of a electrostatic chuck; and

15 Fig. 9 is a drawing illustrating still another embodiment of the configuration of an electrostatic chuck.

DESCRIPTION OF THE INVENTION:

The following describes the first embodiment of the substrate bonding apparatus according to the present invention with reference to drawings:

20 [Configuration of a substrate bonding apparatus]

When broadly classified as shown in Fig. 1, the aforementioned is a substrate bonding apparatus comprises;

a X, Y and θ stage S1 for positioning two substrates 33 and 34 as objects of bonding (wherein the substrate 33
25 mounted and held on table 9 to be described later is referred

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to as "lower substrate 33, while the substrate 34 held on a pressurization plate 16 is called "upper substrate 34");

a substrate bonding unit S2 for bonding substrates 33 and 34; and

5 a Z-axis traveling stage S3 for primary pressurization of substrates 33 and 34 to be described later. These portions S1, S2 and S3 are arranged on the frame 1 sequentially. The X, Y and θ stage S1 is mounted and held on a frame 1, and the substrate bonding unit S2 is supported
10 by a first frame 2 equipped, for example, with four columns installed on the frame 1. The Z-axis traveling stage S3 is supported by a second frame 3 equipped, for example, with four columns installed on the frame 1. The following describes the details of the aforementioned S1, S2 and S3:

15 [X, Y and θ Stage]

The X, Y and θ stage S1 comprises an X-stage 4a arranged on the frame 1, a Y-stage 4b arranged on this X stage 4a, and a θ stage 4c arranged on this Y-stage 4b. The X stage 4a in the present embodiment is designed to move the Y stage
20 4b and θ stage 4c by means of a drive motor 5 in the lateral direction (X axis direction in Fig. 1). The Y stage 4b is configured to move the θ -stage in the in the longitudinal direction (Y axis direction in Fig. 1) by means of a drive motor 6. Further, the θ -stage 4c is configured to rotate
25 in the θ direction as shown in Fig. 1, with respect to the

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Y stage 4b by means of a drive motor 8 through a rotary bearing 7.

In this case, a table 9 carrying the lower substrate 33 is fixed on the θ stage 4c through a support column 10. Further, an arm 11 enclosing the lower side of the support column 10 is mounted on the Y stage 4b through rotary bearing 13 and vacuum seal 14 in such a way that the arm 11 is not turned by the rotation of the support column 10. Also, a vacuum bellows 12 having its one end fixed on the arm 11 and the other end on the lower portion of the vacuum bonding chamber 15 and consisting of a telescopic elastic body covering the support column 10 is located between this arm 11 and a vacuum bonding chamber 15 of the substrate bonding unit S2 to be described later. This serves to maintain the depressurized state in the vacuum bonding chamber 15.

In the present embodiment, one support column 10 is installed approximately at the center of the table 9, but present invention is not restricted thereto. Namely, any number of support columns 10 can be installed so long as it is possible to provide rotation sufficient to compensate for a predetermined value (the amount of displacement of the positioning mark to be described later) of the table 9 resulting from the θ table, for example.

[Substrate bonding unit]

The substrate bonding unit S2 comprises a vacuum

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bonding chamber 15 (vacuum chamber 15) for bonding between two substrates 33 and 34 in a depressurized state, a table 9 arranged in the vacuum bonding chamber 15; and a pressurization plate 16 arranged above the table opposite thereto in the vacuum bonding chamber 15, as shown in Fig. 1. In this case, the table 9 is provided with the lower substrate 33 containing dummy seal 54 to be described later, ultraviolet curing agent 53, adhesive 37 and liquid crystal 39. The pressurization plate 16 carries the upper substrate 34 to be bonded to the lower substrate 33.

A first opening 15a for insertion and removal of substrates 33 and 34 are formed on the side of the aforementioned vacuum bonding chamber 15. A gate valve 17 for blocking this first opening 15a is also provided thereon. Here the gate valve 17 is designed to be freely removable by a cylindrical 17 in the vertical direction (Z-axis direction in Fig. 1).

Further, first and second exhaust pipes for vacuum exhausting inside the vacuum bonding chamber 15 are installed on the lower portion of the vacuum bonding chamber 15. These exhaust pipes 20a and 20b are connected to a vacuum pump through a switching valve (not illustrated). Here the first exhaust pipe 20a is smaller than the second one 20b. For example, assume that both pipes have an approximately circular form. In this case,

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if the diameter of the first one 20a is 1 that of the second one 20b is about 10 to 100 times. Here the diameter of the first exhaust pipe 10a is determined to set the speed in such a way that runaway of substrates 33 and 34 resulting from gas flow, scattering of liquid crystal on the lower substrate 33 or freezing of water content due to depressurization do not occur when the vacuum bonding chamber 15 is evacuated from the first exhaust pipe 20a as will be described later. For example, when the diameter is set, the first exhaust pipe installed has the diameter determined according to the result of experiments conducted by using pipes of different diameters. Here the pressure in the vacuum bonding chamber 15 for the step of bonding in the present embodiment is about 0.67 Pa (5×10^{-3} Torr).

In the present embodiment, the first and second, exhaust pipes 20a and 20b are switched by a switching valve to change the exhaust route, whereby exhaust speed is controlled. However, the present invention is not restricted to this method. For example, it is possible to arrange only one exhaust pipe without two exhaust pipes 20a and 20b provided, as shown in the present embodiment, and to connect this exhaust pipe to a vacuum pump, which is controlled to regulate the exhaust speed. In this case, the exhaust pipe is preferred to have the diameter of the

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greater pipe (that of the second exhaust pipe 20b in the present embodiment).

The table 9 in the vacuum bonding chamber 15 is provided with multiple elevation pins 35 which are used to receive
5 the lower substrate 33 from the transfer unit (not illustrated) or to remove the cell. A cylinder 36 is installed on one end (the bottom in Fig. 1) of these elevation pins 35 to allow movement in the vertical direction through the hole formed in the table 9.

10 Further, the top of the vacuum bonding chamber 15 is provided with a pipe 21 for regaining the atmospheric pressure in the vacuum bonding chamber 15 from depressurized state and a valve 22 which is located on the mid-position of the pipe 21 for introducing gas (air) into
15 the vacuum bonding chamber 15 or shutting it off. Here the pipe 21 is connected to a pressure source such as a pump (not illustrated), which controls the speed of the gas entering the vacuum bonding chamber 15. It should be noted that the pressure source need not always be a provided.

20 The side of the vacuum bonding chamber 15 (opposite to where the aforementioned gate valve 17 is installed) is provided with an atmospheric relief valve 23 comprising a plate-formed body for blocking the approximately circular second opening 15b formed in the vacuum bonding
25 chamber 15, and a cylinder 24 for allowing this atmospheric

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relief valve 23 to be separated from a second opening 15b. As described above, the pressure in the vacuum bonding chamber 15 can be brought back to the atmospheric pressure quickly by allowing the atmospheric relief valve 23 to be
5 separated from the second opening 15b. If the aforementioned pipe 21 has a cross section of approximately circular shape, the diameter of the second opening 15b is preferred to be 5 or more when that of the pipe 21 is assumed as 1.

10 Further, the vacuum bonding chamber 15 is equipped with multiple windows 25 for observing the mark for positioning the upper and lower substrates 33 and 34 through the mark identification hole (not illustrated) formed on the pressurization plate 16. An identification camera 26
15 shown in Fig. 1 is used to observe the aforementioned mark. This camera 26 measures the misalignment of the mark for positioning substrates 33 and 34.

Table 9 is equipped with an electrostatic chucking electrode (not illustrated) for sucking the lower
20 substrate 33 by static electricity or suction force.

Further, the pressurization plate 16 is provided with multiple electrostatic chucks divided into many areas for electrostatic suction. The lead wire from positive and negative elevations of this electrostatic chuck is routed
25 outside the vacuum bonding chamber 15 to permit control

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for each electrostatic chuck.

The electrostatic chucking mechanism is a bipolar electrostatic chuck comprising two or more pairs of electrodes, which ensure the substrates, to be held under vacuum even if there is a change in the size of the substrates to be bonded or in the number of patterns to be produced. The following describes the electrostatic chucking mechanism mounted on the pressurization plate. The same description applies to the electrostatic chucking mechanism mounted on the table.

Figs. 7 and 8 show the general layout of the bipolar electrostatic chuck. For the sake of description, assume that the electrode in white-out lettering in the drawing is a positive electrode and the hatched one a negative electrode.

The bipolar electrostatic chuck in Fig. 7 (a) comprises flat bipolar electrodes 23A and 24A of approximately rectangular shape embedded in two recesses of approximately rectangular shape, respectively. The surface of these bipolar electrodes 23A and 24A (surface on the bottom side of the pressurization plate 16A) is covered with a dielectric where the main surface is flush with the bottom surface of the pressurization plate 16A. In this case, the bipolar electrostatic chuck applies positive voltage to the electrode 23A and negative voltage

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to the electrode 24A, thereby allowing the substrate 34A to be electrostatically chucked onto the pressurization plate 16A by Coulomb force or Johnson Rahbek force.

5 The bipolar electrostatic chuck shown in Fig. (b) has a pair of comb-toothed bipolar electrostatic electrodes 23B and 24B that are embedded in the pressurization plate 16B and has a dielectric embedded therein. Even in this case, this bipolar electrostatic chuck applies positive voltage to the electrode 23B and negative voltage to the electrode 23B, thereby allowing the substrate 34A to be electrostatically chucked onto the pressurization plate 16B by Coulomb force.

Here the entire dimensions of a pair of bipolar electrostatic electrodes 23A and 24A shown in Fig. 7 (a) and bipolar electrostatic electrodes 23B and 24B shown in Fig. 7 (b) are designed slightly smaller than those of the substrate 34A.

By contrast, Fig. 8 (a) and 8(b) show the case where the dimensions of the substrate are smaller than those of a pair of entire electrodes.

In other words, when a small substrate 34B shown in Figs. 8 (a) and (b) is electrostatically chucked by the pressurization plates 16A and 16B equipped with bipolar electrostatic chucks as shown in Figs. 7 (a) and (b), some portions of electrodes 23A, 23B, 24A and 24B are located

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off the substrate 34B. This is because the pressurization plates 16A and 16B are designed so that a big substrate can be pressurized. If voltage (± 100 to ± 5000 volts or thereabout) is applied to the electrodes (dielectric) 23A, 23B, 24A and 24B partly exposed to the vacuum state (a predetermined depressurized atmosphere), electric discharge occurs from the exposed portion, with the result that substrate 34B and electrostatic chuck may be damaged.

As described above, it is possible to handle smaller substrates by reducing the area of the electrode and dielectric to ensure that the dielectric will not be exposed to the vacuum state. However, even when a smaller electrode is used to hold a smaller substrate, it is not possible to produce electrostatic chucking force required to hold a large substrate, so holding is not disabled as a result. Thus, ensuring effective chucking and holding of the substrate requires the entire electrode dimensions to be slightly smaller than those of the substrate.

In recent years, there has appeared a production method of forming multiple liquid crystal substrates on a large board (mother board), and obtaining multiple liquid crystal substrates of a desired size by cutting subsequent to bonding of substrates. In this production method, multiple types of substrates cut out of the mother board are fed to the same production line in some cases. In these

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cases, it is necessary to divide the electrode in conformity to the size of the substrate and to ensure that the voltage-applied electrode (dielectric) is not exposed to the vacuum state and electric discharge does not occur.

5 As described above, the electrostatic chucking mechanism in the present embodiment uses two or more pairs of electrodes. To put it more specifically, the electrostatic chucking mechanism is designed in such a way that multiple electrode pairs each comprising two
10 electrodes formed to permit chuck and hold a substrate having the smallest area are provided on the pressurization plate. It is a bipolar electrostatic chuck capable of handling both large and small substrates by switching in conformity to the size of the substrate the electrode where
15 the positive and negative voltages are applied. The bipolar electrostatic chuck is equipped with voltage application means for applying voltage to a desired electrode pair. For example, the aforementioned voltage application means may be designed in such a way that the
20 operator switches the electrode for voltage application in conformity to the substrates to be bonded together as required. Alternatively, it may be configured in such a way that a desired electrode is selected for each loaded substrate by preliminarily entering various types of
25 information on the dimensions of the substrates to be

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loaded into the system. Fig. 9 shows the pressurization plate 16 equipped with two electrode pairs each comprising two electrodes. For the sake of description, assume that the electrode in white-out lettering in the drawing is a positive electrode and the hatched one a negative electrode.

As shown in Fig. 9 (a) and (b), the bipolar electrostatic chuck according to the present embodiment is configured so that flat electrodes of approximately rectangular shape 23D1, 24D1, 23D2 and 24D2 are embedded in four recesses of approximately rectangular shape formed on the lower surface of the pressurization plate 16D, and the surfaces of the electrodes of approximately rectangular shape 23D1, 24D1, 23D2 and 24D2 (surface on the bottom surface of the pressurization plate 16D) are covered with a dielectric where the main surface is flush with the bottom surface of the pressurization plate 16D. In this case, this bipolar electrostatic chuck applies positive voltage to the electrodes 23D1 and 23D2 to make them positive, and negative voltage to the electrodes 24D1 and 24D2 to make them negative, whereby the substrate is electrostatically chucked by the pressurization plate 16 and is held in position.

In the case of a large upper substrate 34D, a big chucking force is produced by application of voltage to

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all electrodes 23D1, 24D1, 23D2 and 24D2, and the upper substrate 34D is chucked and held in position, as shown in Fig. 9 (a). Further, in the case of a small upper substrate 34E, necessary and sufficient chucking force is
5 obtained by application of voltage to only the adjacent positive and negative poles (a pair of electrodes 23D2 and 24D1 arranged in the vicinity of the center of the pressurization plate 16D according to the present embodiment), as shown in Fig. 9 (b), and the upper substrate
10 34D is chucked and held in position. In this case, no voltage is applied to the remaining electrodes 23D1 and 24D2, and this prevents electric discharge from occurring, as in the prior art methods.

As described above, when the size of the substrate has
15 changed, the substrates of several types of substrates can be firmly chucked under vacuum and held in position by increasing the number of electrode pairs to 3, 4, 5 or the like in conformity to the size of the substrate. In other words, since multiple pairs of the electrodes for
20 electrostatic chuck in conformity to the shape of the substrate having the smallest area are installed on the pressurization plate (table to be described later), the substrate can be chucked and held in position by great chucking force, independently of the sizes of the substrate.
25 In the present embodiment, a row of electrodes provided

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in the lateral direction are shown as an example. However, the present invention is not restricted thereto. For example, multiple rows of electrodes can be provided in the longitudinal direction, and also multiple bipolar comb type electrodes can be provided.

As described above, the electrode for electrostatic chucking electrode is a flat one of approximately rectangular shape in the present embodiment. Electrodes are each mounted in multiple recesses of approximately rectangular shape. Further, the surfaces of electrostatic chucking electrodes (the top surface of the table) are covered with dielectric, and the main surface of the dielectric is flush with the top surface of the table 9. The electrostatic chucking electrode mounted on the table is connected to a positive/negative D.C. power source through an appropriate positive/negative switch. Accordingly, if positive or negative voltage is applied to each electrostatic chucking electrode, the lower substrate 33 is electrostatically chucked by the table 9. Here the voltage applied to each electrostatic chucking electrode may be homopolar or bipolar with different polarities.

When the atmospheric pressure is in the vacuum bonding chamber 15, it is preferred to use the aforementioned chucking method by means of a suction hole 9a. This is

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because, when electrostatic chucking is used, electric discharge will occur due to electrostatic discharge if there is a layer of air between the lower substrate 33 and table 9. This may result in the damage of the lower
5 substrate 33 or table 9. For example, when the lower substrate 33 is first brought in contact with the table 9 and is held in position, vacuum suction is performed to reduce pressure in the vacuum chamber since it is surrounded with atmospheric pressure. It is preferred to
10 start electrostatic chucking after pressure has been reduced to the point where electric discharge does not occur.

Each suction hole 9a is connected to the suction valve (not illustrated) provided outside the vacuum bonding
15 chamber 15 and is connected to the vacuum pump (not illustrated) through this suction valve. In this case, a bypass valve is provided at some midpoint in the pipe 18 for releasing to the atmosphere through a vacuum suction releasing valve or introducing pressure gas. The state of
20 vacuum suction is forcibly released by releasing to the atmosphere through this vacuum suction releasing valve or introducing pressure gas. The table 9 configured in this manner is fixed on the θ stage 4c through the support column 10, as described above.

25 Similarly to the table 9, the pressurization plate 16

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is equipped with an electrostatic chucking electrode for chucking the upper substrate 34 and multiple suction holes 16a. As will be described later, if the pressure in the vacuum bonding chamber 15 is reduced with the upper

5 substrate 34 chucked by the pressurization plate 16, the chucking force will be reduced and the upper substrate 34 may be dropped. To avoid this, a substrate holding pawl (not illustrated) for receiving the upper substrate 34 at the position slightly below the pressurization plate 16

10 is provided in the vacuum bonding chamber 15. This substrate holding pawl is arranged, for example, to conform to the two angles at the diagonal position of the upper substrate 34. It is lifted and held by a shaft extending downward from the top of the vacuum bonding chamber 15.

15 To put it more specifically, a shaft is inserted through a penetration hole formed on the upper portion of the vacuum bonding chamber 15 (not illustrated). This shaft is designed to rotate around its axis and to move in the vertical direction. In this case, the shaft is

20 covered with the vacuum seal so that the vacuum leakage does not occur in the vacuum bonding chamber 15. The aforementioned rotation of the shaft is given by the rotary actuator (not illustrated) connected to the end of the shaft, and the movement in the vertical direction is given

25 by an elevation actuator (not illustrated) connected to

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the end of the shaft. As described above, substrates 33 and 34 are bonded together by rotation or vertical movement of the shaft. The substrate holding pawl can be retracted so that there is no interference when the liquid crystal agent dripped on the lower substrate 33 is spread in the
5 extending direction of the main surface of each of substrates 33 and 34.

The aforementioned suction hole 16a is connected to the suction valve (not illustrated) mounted outside the
10 vacuum bonding chamber 15 through the pipe 19, and is connected to a vacuum pump (not illustrated) through this suction valve. In this case, a bypass pipe for releasing to atmosphere through the suction releasing valve is provided at a midpoint of this pipe 19, similarly to the
15 table 9. The state of vacuum suction is forcibly released by releasing to the atmosphere through this vacuum suction releasing valve or introducing pressure gas. The pressurization plate 16 configured in this manner is suspended from the traveling base 29 (to be described
20 later) of the Z-axis traveling stage S3 through multiple support columns 27, and is held in position.

A vacuum bellows 28 having one end fixed on the vacuum bonding chamber 15 and the other end fixed on the traveling base 29 and consisting of a telescopic elastic body
25 covering the support column 27 is located between the

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vacuum bonding chamber 15 and traveling base 29. This serves to maintain the depressurized state in the vacuum bonding chamber 15.

Further, as shown in Fig. 1, the top of this vacuum bonding chamber 15 is provided with the temporary securing mechanism S4 for hardening the ultraviolet curing agent 53 for temporary securing placed in advance on the lower substrate 33 by application of both pressure and ultraviolet rays, with the pressurization plate 16 in the raised position, subsequent to primary pressurization to be described later (subsequent to bonding substrates 33 and 34 together by pressure in a depressurized state). The following describes the temporary securing mechanism S4 with reference to Fig. 2.

The temporary securing mechanism S4 comprises;

- a glass holder 42 consisting of a cylinder for holding glass 44 inside from the tip portion (located in the vacuum bonding chamber 15);
- a hollow cylindrical pressure bar 69 fixed with this glass holder 42 by a screw;
- a ultraviolet fiber 45 for ultraviolet irradiation located inside this hollow cylindrical pressure bar 60 and in the vicinity of glass 44;
- a flange 50 fixed on the top surface of the vacuum bonding chamber 15 through vacuum cut-off O-ring 46 and

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comprising a cylinder through which the hollow cylindrical pressure bar 60 is inserted; and

means for traveling the hollow cylindrical pressure bar 60 in the vertical direction.

5 Traveling means of the present embodiment comprises;
a cylinder 49 for driving the vertical traveling of the hollow cylindrical pressure bar 60;

a cylinder fixture 52 for fixing the cylinder 49 arranged on the outer periphery of the flange 50; and

10 a connecting fitting 48 arranged on one end (top end in Fig. 2) of the hollow cylindrical pressure bar 60 and fixed on the operating section (traveling shaft) of the cylinder 49. A bearing 51 is mounted in the flange 50 to ensure that the hollow cylindrical pressure bar 60 moves
15 smoothly in the vertical direction. Here if the hollow cylindrical pressure bar 60 moves in the vertical direction, the ultraviolet fiber 45 also moves in the vertical direction. In order to avoid damage of an ultraviolet fiber 45 extending from one end of the hollow cylindrical
20 pressure bar 60, the extended portion is fixed to the connecting fitting 48 by means of the fixture 55. Fixing in this manner reduced the stress applied to the ultraviolet fiber 45 at the time of vertical traveling, with the result that possible rupture can be avoided, for
25 example.

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The tip of the glass holder 42 is provided with a cylindrical constricted area in contact with the lower surface of glass 44. So as will be described later, even if the constricted area is pressed against the substrate, no pressure is applied to the adjacent ultraviolet curing agents 53 simultaneously, because the pressed surface is small. Further, the constricted area serves as a port for irradiation of ultraviolet rays, so the ultraviolet rays through the glass 44 is not directly applied to the substrate.

An O-ring 41 for vacuum shut-off is arranged on the joint end between the glass holder 42 and hollow cylindrical pressure bar 60, and an O-ring 43 for vacuum shut-off is mounted between the glass holder 42 and glass 44. An O-ring 46 for vacuum shut-off is mounted between the top surface of the vacuum bonding chamber 15 and bottom surface of the flange 50, and an O-ring 47 for vacuum shut-off is installed between the inner periphery of the flange 50 and the outer periphery of the hollow cylindrical pressure bar 60. This arrangement maintains the depressurized state in the vacuum bonding chamber 15. In other words, pressure in the hollow cylindrical pressure bar 60 reaches the atmospheric pressure. This portion is utilized to place the ultraviolet fiber 45 closest to the substrate structurally (for example, in the vicinity of

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glass 44). Since the ultraviolet fiber 45 is mounted in this position, there is a very little attenuation in the ultraviolet rays applied to the substrate. There is no need of installing a large-diameter condenser lens. For this reason, the material characterized by the best ultraviolet ray transmittance, for example, quartz glass, is best suited as glass 44.

Multiple temporary securing mechanisms S4 configured in this manner can be mounted by studying the effective bonding position, if practicable from the viewpoint of designing. As shown in Fig. 3, it is preferred to arrange them at two or more positions on each side of the substrate (above the ultraviolet rays curing agent 53 in Fig. 3). Further, if depressurized state in the vacuum bonding chamber 15 can be maintained, the temporary securing mechanism S4 can be provided with a traveling mechanism that allows horizontal traveling on the substrate, and one temporary securing mechanism S4 can be provided on each side of the substrate.

[Z-axis traveling stage]

The Z-axis traveling stage comprises;

a traveling base 29 for suspending the pressurization plate 16 and holding it;

linear guides arranged on both ends thereof;

a vertical rail 3a (Z-axis direction shown in Fig. 1)

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engaged with this linear guide 30 and provided on the frame
3;

an electric motor 34 equipped with an output shaft in
the Z-axis direction; and

5 a ball screw 31 with the one end engaged with the side
of the traveling base 29 and the other end engaged with
the output shaft side of the electric motor 32. The Z-
axis traveling stage S3 configured in this manner allows
the motor base 29 to be fed along the rail by the electric
10 motor 32 in the vertical direction, and permits the
pressurization plate 16 to be fed in the vertical
direction.

[Operation of the substrate bonding apparatus]

The following describes the operation of the substrate
15 bonding apparatus according to the present embodiment.
Here reference will be made of the case where a substrate
for liquid crystal panel is used as a substrate to be bonded.

As shown in Fig. 3, a continuous frame is provided in
advance on one of the two substrates to be bonded together,
20 using liquid crystal sealing compound (adhesive) 37 in
order to confine and seal liquid crystal in a predetermined
frame when the substrates are bonded together. Similarly,
a continuous frame 54 (hereinafter referred to as "dummy
seal") is provided separately from adhesive 37 so as to
25 enclose the aforementioned frame. Ultraviolet curing

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agent 53 is provided in a punctual or linear form (having some length) in the vicinity of the substrate end of the dummy seal 54. A predetermined amount of liquid crystal 39 is dripped into the liquid crystal sealing frame comprising adhesive 37. In the present embodiment, the substrate with this liquid crystal 39 dripped thereon is used as a lower substrate 33. In some cases, dummy seal 54 is not provided. In such cases, the ultraviolet curing agent 53 is provided at approximately the equivalent position.

The peripheral portion of the upper substrate 34 with the film surface facing downward is sucked from the bottom, using the hand of the transfer unit (not illustrated) installed outside the vacuum bonding chamber 15. Then the gate valve 17 at the first opening 15a of the vacuum bonding chamber 15 is opened, and the hand of the transfer unit is inserted into the vacuum bonding chamber 15 from the first opening 15a. The pressurization plate 16 lowered by the operation of the electric motor 32 is pressed against the upper substrate 34. After that, suction of the hand is released and the vacuum pump is operated to allow the upper substrate 34 to be sucked by the pressurization plate 16 through the suction hole 16a. Upon completion of suction of the upper substrate 34, the hand is retracted out of the vacuum bonding chamber 15.

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Then each elevation pin 35 is raised by the operation of the cylinder 36 in such a way that the tip thereof will project from the top surface of the table 9. The peripheral portion of the lower substrate 33 with the liquid crystal-dripped surface facing upward is sucked by the hand of the transfer unit from below, and the hand is inserted into the vacuum bonding chamber 15 so that the lower substrate 33 is transferred onto each elevation pin 35. Upon completion of the transfer of the lower substrate 33, the hand is retracted out of the vacuum bonding chamber 15, and the gate valve 17 is closed. After that, each elevation pin 35 is lowered and the lower substrate 33 is placed on the table 9. The vacuum pump is operated to allow the lower substrate 33 to be sucked by the table 9 through suction hole 9a.

Upon termination of the substrates 33 and 34 being sucked by the table 9 and pressurization plate 16, the valve on the side of the first exhaust pipe 20a is opened to discharge gas gradually from the vacuum bonding chamber 15. To put it more specifically, in the present embodiment, the initial state of the apparatus is preset in such a way that the first and second exhaust pipes 20a and 20b are both closed by the switching valve. Upon termination of the substrates 33 and 34 being sucked, the switching valve is changed so that the side of the first exhaust pipe 20a

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is opened and the side of the second exhaust pipe 20b is closed, and gas is gradually discharged from the vacuum bonding chamber 15. In this case, gas is discharged at a low speed using the first exhaust pipe 20a with its diameter set to the aforementioned value in such a way that runaway of substrates 33 and 34 resulting from gas flow, scattering of liquid crystal on the lower substrate 33 or freezing of water content due to depressurization do not occur.

The valve of the first exhaust pipe 20a is closed when the pressure in the vacuum bonding chamber 15 has reached a predetermined level due to discharge of gas through the exhaust pipe 20a, - to put it more specifically, when the pressure in the vacuum bonding chamber 15 measured by a pressure gauge (not illustrated) has reached the level where runaway of the substrate, scattering of liquid crystal and freezing of moisture content do not occur even if the exhaust speed is raised (for example, when the pressure has been reduced to the extent that upper substrate 34 sucked by suction force is not separated).

Then the valve of the second exhaust pipe 20b is opened and the pressure in the vacuum bonding chamber 15 is quickly reduced to the level required to bond substrates 33 and 34 (about 0.67 Pa in the present embodiment). Here the pressure in the vacuum bonding chamber 15 is lower than the suction force of the upper substrate 34 under the

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current pressure level, so the upper substrate 34 is separated from the pressurization plate 16. However, the lower surface of the pressurization plate 16 is equipped with the aforementioned substrate holding pawl, and the substrate holding pawl is driven by the aforementioned rotating actuator and elevator actuator so that the upper substrate 34 in position is held in position. This keeps the upper substrate 34 in the specified position without being separated.

As described above, upon termination of depressurization in the vacuum bonding chamber 15, voltage is applied to the electrostatic chucking electrode to ensure that substrates 33 and 34 can be sucked by the table 9 and pressurization plate 16 even in vacuum; thus, the substrates 33 and 34 are chucked electrostatically. After that, the electric motor 32 is driven to lower the traveling base 29 so that the upper substrate 34 is brought closer to the lower substrate 33. An identification camera 26 is used to observe the position adjustment mark located at the substrates 33 and 34 and to measure the displacement between substrates 33 and 34. Based on this measurement, the operations of the X stage 4a, Y stage 4b and θ stage 4c are controlled, and the table 9 is moved in the horizontal direction, thereby ensuring high precision positioning between the lower substrate 33 and upper substrate 34.

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Upon termination of the aforementioned positioning, the traveling base 29 is further lowered and ultraviolet curing agent 53, dummy seal 54 and adhesive 37 are crushed by the upper substrate 34. The frame formed by the adhesive
5 37 is filled with the liquid crystal. Then the primary pressurization terminates. Subsequent to the primary pressurization, the voltage applied to the electrostatic chucking electrode of the pressurization plate 16 is cut off, and the electric motor 32 is driven to raise the
10 pressurization plate 16.

Fig. 4 shows the state of the substrates 33 and 34 subsequent to primary pressurization. The interval between the substrates 33 and 34 in this case is about 15 microns, without reaching the desired interval. So the
15 crushed amount of adhesive 37 is insufficient, and the contact area of the adhesive 37 with substrates 33 and 34 is also insufficient (length of the contact portion is insufficient). As a result, the state of bonding is not complete. Further, liquid crystal 39 in the frame of
20 adhesive 37 fails to spread with the result that a big vacuum space 40 is created in liquid crystal 39.

If the pressure in the vacuum bonding chamber 15 is changed from the depressurized state to atmospheric pressure, a high external pressure is approximately
25 uniformly applied to the substrates 33 and 34 since the

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space between substrates 33 and 34 (the aforementioned vacuum space 40) is in a depressurized state. For example, when the substrates 33 and 34 have dimensions of 1,200 mm × 1,000 mm, atmospheric pressure is applied if the space
5 between substrates 33 and 34 is in a depressurized state. Then a force of 121.6 kN can be applied. So in the present embodiment, secondary pressurization is performed as will be described later, and an adequate substrate space of 5 microns or less, - preferably, 4 microns or less - is
10 obtained.

As described above, if the depressurized state in the vacuum bonding chamber 15 is changed to atmospheric pressure subsequent to primary pressurization, approximately uniform pressure can be applied to each of
15 substrates 33 and 34. However, if the pressure is reset to the atmospheric pressure suddenly, the adhesive 37 is not sufficiently crushed, as described above. So gas introduced into the vacuum bonding chamber 15 breaks the dummy seal 54 and adhesive 37 to enter the vacuum space
20 40, making the liquid crystal board non-conforming. Alternatively, in the middle of feeding out subsequent to return to atmospheric pressure, compressive force is applied to the sealed surface of one of the substrates and tensile strength is applied to the sealed surface of the
25 other substrate, as in the case of the aforementioned prior

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art example, with the result that misalignment is produced between the upper and lower substrates 33 and 34. This will result in the sealed portion (adhesive 37 and dummy seal 54) being collapsed and the liquid crystal 39 spilling out.

5 Thus, a non-conforming liquid crystal board will be created.

To solve this problem in the present embodiment, the ultraviolet curing agent 53 provided apart from the adhesive 37 and dummy seal 54 is locally pressurized until
10 the final gap (adequate, namely, desired substrate spacing) is reached, subsequent to primary pressurization and prior to secondary pressurization. After that, the ultraviolet curing agent 53 is subjected to ultraviolet irradiation, thereby ensuring temporary securing. The
15 following describes the temporary securing with reference to Fig. 5:

In the first step, a cylinder 49 given in Fig. 2 is driven to lower the hollow cylindrical pressure bar 60 from above the ultraviolet curing agent 53 in substrates 33 and
20 34. The tip of the constricted portion of the glass holder 42 is used to apply a predetermined to each of the substrates 33 and 34 so that the space between substrates will reach the final gap. Under this condition, ultraviolet rays are applied from the ultraviolet fiber. The ultraviolet rays
25 are applied to the ultraviolet curing agent 53 through the

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vacuum-blocked glass 44, so the ultraviolet curing agent 53 is hardened to provide temporary securing. When the glass holder 42 is pressed against the substrate, the pressure is preferred to be 0.1 to 0.5 MPa, although it
5 varies with the ultraviolet curing agent 53.

After temporary securing has been made as described above, the cylinder 24 is operated and atmosphere release valve 23 is opened to regain atmosphere in the vacuum bonding chamber 15 suddenly, and pressure is applied to
10 substrates 33 and 34 (secondary pressurization). As described above, this step allows pressure to be applied to substrates 33 and 34, whereby substrates 33 and 34 are subjected to post bonding.

As described above, subsequent to primary
15 pressurization in a depressurized state, pressure is applied to the ultraviolet curing agent 53 for temporary securing provided at other than the sealed portion (adhesive 37, dummy seal 54) to a desired level until the curing agent is hardened. Then the atmospheric pressure
20 in the vacuum bonding chamber 15 is regained and the substrates are post-bonded with each other, according to the configuration of the present embodiment. So even if the pressure in the vacuum bonding chamber 15 is suddenly returned to the atmospheric pressure, it is possible to
25 prevent leakage of liquid crystal 39 resulting from

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collapse of the sealed portion in the half-bonded state or misalignment between substrates.

As described above, when the step of bonding has been completed and pressure in the vacuum bonding chamber 15
5 has reached the atmospheric pressure, the gate valve 17 opens. Then the hollow cylindrical pressure bar 60 is raised to cut off the voltage applied to the electrostatic chucking electrode of table 9 and to release the suction through the suction hole 9a. After that, each elevation
10 pin 35 is raised to push up the cell from the top of the table 9. Thereafter, the hand of the transfer unit is inserted under the bottom of the cell (between the cell and table 9). The cell is transferred onto the hand, and fed out of the vacuum bonding chamber 15.

15 After temporary securing, the following step may be taken without regaining the atmospheric pressure suddenly in the vacuum bonding chamber 15: In the first place, the valve 22 of a slender pipe 21 is opened subsequent to temporary securing, and pressurized gas is led into the
20 vacuum bonding chamber 15 from the pressure source connected to the pipe 21, whereby atmospheric pressure is gradually regained. If atmospheric pressure is gradually regained as described above, pressure is applied to the substrates 33 and 34 gradually, and the sealed portion
25 (adhesive 37 and dummy seal 54) is gradually collapsed,

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with the result that contact area between the sealed portion and each of substrates 33 and 34 is gradually increased. This method provides a gradual increase in pressure difference between the internal pressure of the vacuum space 40 and the pressure of the vacuum bonding chamber 15, thereby ensuring effective prevention of the introduced gas from entering the vacuum space 40.

For example, the space between the substrates 33 and 34 is about 10 microns. As described above, if gas is introduced into the vacuum bonding chamber 15, adhesive 37 is crushed, whereby flowing occurs and viscosity reduces due to thixotropicity. When the viscosity is lowered, the atmosphere releasing valve 23 is suddenly opened to regain the atmospheric pressure in the vacuum bonding chamber 15. Pressure is further added to substrates 33 and 34. To put it more specifically, a pressure gauge installed inside the vacuum bonding chamber 15 has been detected to have exceeded a predetermined level, the valve 22 is closed and the cylinder 24 is actuated to open the atmosphere releasing valve 23, whereby pressure is applied to each of substrates 33 and 34. Then the bonding step is now complete. For example, to determine the predetermined pressure, an experiment is conducted in advance to measure the pressure where the introduced gas ceases to break the adhesive 37 to enter the vacuum space 40. This pressure

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value is set.

Sudden regaining of atmospheric pressure in the vacuum bonding chamber 15 through the aforementioned step allows the contact area of the adhesive 37 to be expanded with respect to substrates 33 and 34, and improves the sealing property. This ensures effective prevention of the entry of gas between the substrates 33 and 34. Further, the adhesive 37 is quickly crushed since its viscosity is reduced, and the liquid crystal 39 is also crushed and spread by pressure, with the result that bonding of the substrates 33 and 34 can be achieved in a shorter time.

It is also possible to introduce gas through the aforementioned pipe 21 and valve 22, subsequent to primary pressurization, and to perform the aforementioned temporary securing subsequent to the above-mentioned predetermined pressure having been reached. In this case, atmospheric pressure in the vacuum bonding chamber 15 is suddenly regained after temporary securing, and post-bonding is carried out.

[Second Embodiment]

The following describes a second embodiment of the substrate bonding apparatus according to the present invention with reference to Fig. 6:

This substrate bonding apparatus is different from that of the above-mentioned first embodiment in the

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following points. Otherwise, they are designed in the same configuration. To put it more specifically, the temporary securing mechanism S4 characterized by the same configuration as that of the first embodiment is arranged
5 on the lower portion of the vacuum bonding chamber 15. This temporary securing mechanism S4 has the same functions as those of the elevation pin 35 of the first embodiment. As a result, the present embodiment permits raising of the substrate and temporary securing by ultraviolet rays - the
10 same function as that in the first embodiment - without using any elevation pin 35. This means reduction in the working time.

As described above, this temporary securing mechanism S4 configured in the present embodiment prevents leakage
15 of liquid crystal due to collapse of the sealed portion and misalignment of the substrates when atmospheric pressure in the vacuum bonding chamber 15 has to be regained suddenly. Namely, this configuration provides the same advantage as that of the first embodiment. Not only that,
20 this configuration prevents a substantial increase in the number of components constituting the apparatus.

According to the substrate bonding method and apparatus of the present invention, the distance between substrates on the portion where adhesive for temporary
25 securing is provided can be adjusted to a desired gap in

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a depressurized state. At the same time, temporary securing is possible in such a position, with the result that a desired distance between substrates can be maintained in the final stage. Further, even in the case of the cell composed of two large-sized substrates as in the prior art example, a desired distance between substrates can be maintained in the final stage. Accordingly, it is possible to avoid displacement of upper and lower substrates during transport. These features prevent non-conforming products from being produced.

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WHAT IS CLAIMED IS:

1. A substrate bonding method comprising;
a primary pressurization step of reducing the distance between two substrates arranged opposite to each other after having been positioned in a vacuum bonding chamber 15 in a depressurized state wherein at least one of the two is coated with adhesive, and
a secondary pressurization step of pressuring and bonding said substrates by regaining atmospheric pressure in a vacuum bonding chamber;
said substrate bonding method characterized in that
at least one of said substrates is provided with a liquid crystal sealing adhesive and a ultraviolet curing agent, and
a temporary securing step is arranged between said primary and secondary pressurization steps wherein said ultraviolet curing agent in the respective substrate having completed said primary pressurization step is hardened by simultaneously application of pressure and ultraviolet rays in said vacuum chamber in a depressurized state .
2. A substrate bonding method comprising;
a vacuum chamber wherein two substrates to be bonded are pressurized and bonded together,

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a table arranged in said vacuum chamber and used for holding one of said substrates on which liquid crystal is dripped, and

a pressurization plate arranged in said vacuum chamber and used for holding the other substrate placed opposite to said one;

said substrate bonding method characterized in that said vacuum chamber incorporates a temporary securing step wherein;

a liquid crystal sealing adhesive and a ultraviolet curing agent are provided at multiple positions of at least one of said substrates is hardened by simultaneously application of pressure and ultraviolet rays in said vacuum chamber in a depressurized state, after said substrates have been subjected to primary pressurization by reducing the distance between said table and a pressurization plate in said vacuum chamber.