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TITLE OF THE INVENTION

METHOD OF MANUFACTURING LIQUID CRYSTAL DISPLAY PANEL
AND LIQUID CRYSTAL DISPLAY PANEL MANUFACTURING
APPARATUS

5

BACKGROUND OF THE INVENTION

This invention relates to a method of
manufacturing a liquid crystal display panel and a
liquid crystal display panel manufacturing apparatus.

Generally, a liquid crystal display panel is
10 formed by superposing a pair of glass substrates with
spacers interposed therebetween, bonding the substrates
with a frame-shaped sealing member, and injecting
liquid crystal into a space surrounded by the sealing
member and the substrates. The spacers are arranged
15 between the pair of substrates to keep a gap between
the substrates uniform with a predetermined thickness.
Thereby, a uniform display quality over the whole
screen is secured. As the spacers, used are spherical
spacers such as plastic beads scattered on a substrate,
20 rod spacers such as glass fibers, or columnar spacers
arranged in desirable parts on the substrate by
photolithography in which photo-sensitive resin is
applied on the substrate and subjected to exposure and
development.

25

In a method of manufacturing a liquid crystal
display panel having the above structure, two
substrates in each of which transparent electrodes and



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alignment films are formed are bonded together, and thereafter liquid crystal is injected into the space between the substrates. A vacuum method is used as a general liquid crystal injecting method. In the vacuum
5 method, first, an empty display panel with a liquid-crystal intake opened is arranged in a vacuum apparatus, and the display panel is evacuated. In this state, the liquid-crystal intake is immersed in a liquid crystal boat filled with liquid crystal, and then the pressure
10 is gradually returned to atmospheric pressure to inject the liquid crystal into the display panel. Further, proposed is a method of shortening the injecting time by raising the temperature of the display panel during injection of liquid crystal under atmospheric pressure
15 to lower viscosity of the liquid crystal. This method is called heating injection.

After the liquid crystal injecting step, the liquid-crystal intake is sealed. As disclosed in, for example, Jpn. Pat. appln. KOKAI publication NO. 2-87114,
20 the sealing method is pressurizing sealing method in which the liquid-crystal intake is sealed in the state where the liquid-crystal-injected display panel is pressurized. Further, Example of the sealing method is heating sealing method in which the liquid-crystal
25 intake is sealed in the state where the liquid-crystal-injected display panel is heated.

Usually, display panels are carried at room

temperature (about 25°C) from injecting step to sealing step. Therefore, when a liquid crystal display panel subjected to heating injection is put into the sealing step, the temperature of the liquid crystal display panel falls to about room temperature.

According to the liquid crystal display panel structured as described above, in environments of room temperature, the gap between the substrates is kept uniform by the spacers, and the thickness of the liquid crystal held in between the substrates is kept uniform in each part. Therefore, the liquid crystal display panel can perform good image display.

However, spacers and liquid crystal forming liquid crystal display panel expand in high-temperature environments. In particular, the expansion coefficient of liquid crystal is much greater than those of spacers and glass and the like. If the panel is used in high temperature environments, unevenness in display occurs due to the difference in the expansion coefficient.

Generally, the coefficient of linear expansion of columnar spacers containing pigments is about 0.8×10^{-4} [$^{\circ}\text{C}$] or less, while the coefficient of linear expansion of liquid crystal is 2.5×10^{-4} [$^{\circ}\text{C}$]. For example, supposing that the gap between the substrates of a liquid crystal display panel at normal temperature (room temperature) is 5.00 [μm], under a high-temperature of 50°C, the columnar spacers expand to have

the height of 5.01 [μm], while the thickness of the thermal-expanded liquid crystal layer is 5.10 [μm].

Therefore, the thermal-expanded liquid crystal presses the substrates outward, and the substrates are deformed to bulge out. As a result, the spacers held between the substrates are separated from the substrates, and lose the function of maintaining the gap between the substrates. Further, the liquid crystal increased in volume by thermal expansion moves in the panel, and the space between the substrates is deformed to wave.

If the liquid crystal display panel in this state is vertically stood up, the liquid crystal increased in volume in the liquid crystal layer gathers in a lower portion of the liquid crystal display panel due to its own weight. As a result, the thickness of the liquid crystal layer increases in the lower portion of the liquid crystal display panel, and thereby unevenness in display occurs in image display and the display quality deteriorates.

To solve such a problem, in the sealing step, the liquid crystal intake is sealed after pressurizing the panel to discharge excess liquid crystal. In such a case, the liquid crystal is discharged from the narrow liquid crystal intake. Therefore, it takes at least 1 hour to discharge the excess liquid crystal, and all the discharged liquid crystal is discarded and wasted.

This invention has been made in view of the above points. The object of the present invention is to provide a method and an apparatus of manufacturing a liquid crystal display panel which can constantly maintain a good display quality without being influenced by the temperature of its use environment.

BRIEF SUMMARY OF THE INVENTION

To solve the above problem, a method of manufacturing a liquid crystal display panel according to an aspect of the present invention comprises:

bonding a pair of substrates to each other with a gap maintained therebetween, and defining an intake between the substrates;

injecting liquid crystal into a space between the substrates through the intake in an environment heated in comparison with room temperature; and

sealing the intake by a sealant, with the environment kept heated from the injecting of the liquid crystal, in which the temperature during sealing is higher than the temperature during injecting to control the width of the sealant.

Further, a liquid crystal display panel manufacturing apparatus according to another aspect of the present invention comprises:

a chamber including a liquid crystal boat to inject liquid crystal into a space between a pair of substrates, an applying mechanism which applies a sealant to the pair of substrates, and a heater.

Additional advantages of the invention will be set

forth in the description which follows, and in part
will be obvious from the description, or may be learned
by practice of the invention. The advantages of the
invention may be realized and obtained by means of the
5 instrumentalities and combinations particularly pointed
out hereinafter.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

The accompanying drawings, which are incorporated
in and constitute a part of the specification,
10 illustrate embodiments of the invention, and together
with the general description given above and the
detailed description of the embodiments given below,
serve to explain the principles of the invention.

FIG. 1 is a plan view of a manufacturing apparatus
15 comprising an injecting device, a carrying mechanism
and a sealing device, according to an embodiment of the
present invention.

FIG. 2 is a cross-sectional view of a liquid
crystal display panel at normal temperature according
20 to the embodiment of the present invention.

FIG. 3 is a perspective view of the liquid crystal
display panel shown in FIG. 2.

FIG. 4 is a schematic diagram of the liquid
crystal display panel, illustrating a liquid crystal
25 intake, in particular, a sealant suction width.

FIG. 5 is a plan view of a modification of the
manufacturing apparatus according to the embodiment of

the present invention, which comprises an injecting device and a sealing device.

DETAILED DESCRIPTION OF THE INVENTION

A manufacturing method and a manufacturing
5 apparatus of a liquid crystal display panel according to embodiment of the present invention will now be explained in detail with reference to drawings.

First, explained is a structure of a liquid
crystal display panel manufactured by the manufacturing
10 method.

As shown in FIGS. 2 and 3, a liquid crystal
display panel 1 comprises a first substrate 2 and a
second substrate 4 which are arranged opposite to each
other. The first substrate 2 and the second substrate
15 4 are held, with a predetermined gap between them, by a plurality of columnar spacers 3 formed on one of the substrates. The first substrate 2 is provided with gate wirings, source wirings, switching elements, pixel electrodes and an alignment film, which are not shown.
20 Further, the second substrate 4 is provided with a common electrode and an orientation film, which are not shown.

Edge portions of the first and the second
substrates 2 and 4 are bonded by a frame-shaped sealing
25 member 5. A liquid crystal intake 7 is formed in the sealing member. Liquid crystal is injected in an area enclosed by the first substrate 2, second substrate 4

and the sealing member 5 to form a liquid crystal layer 6. The liquid crystal intake 7 is sealed with a sealant 8.

5 Next, detailed are the manufacturing method and the manufacturing apparatus of the liquid crystal display panel structured as described above.

10 As shown in FIG. 1, a manufacturing apparatus 10 which manufactures the liquid crystal display panel 1 comprises an injecting device 11 which performs liquid crystal injection, a sealing device 13 which performs sealing, and a carrying mechanism 12 which carries a liquid crystal display panel between the injecting device and the sealing device.

15 The injecting device 11 comprises an injecting chamber 14 which functions as a liquid crystal injecting chamber for holding an empty display panel 1a and liquid crystal. In the injecting chamber 14, a heater 18a serving as first heating means and a liquid crystal boat 19 are provided. The injecting device 11
20 also has a liquid crystal feeder 20 which feeds liquid crystal to the liquid crystal boat 19, and an evacuating device 21 for evacuating the injecting chamber 14 and the display panel 1a set in the injecting chamber.

25 The sealing device 13 comprises an applying chamber 16 which holds the display panel 1a injected with liquid crystal. In the applying chamber 16

serving as an application chamber, provided are a liquid crystal wiping section 13a, an applying mechanism 13b which applies the sealant 8 to the panel, a waiting section 13c, and a heater 18c serving as
5 second heating means for heating the inside of the applying chamber. The sealing device 13 also has a curing chamber 17 which functions as an ultraviolet irradiation chamber. In the curing chamber 17, provided are an ultraviolet irradiating section 13d and
10 a heater 18d serving as heating means for heating the inside of the curing chamber.

The carrying mechanism 12 has a carrier 15 which is provided to be movable between the injecting chamber 14 and the applying chamber 16. In the carrier, a
15 carrying chamber 22 serving as a carrying chamber which holds the display panel 1a is formed. Further, the carrier 15 is provided with a heater 18b which heats the inside of the carrying chamber 22. As a modification of the above manufacturing apparatus 10,
20 there may be no carrying mechanism 12, and the injecting chamber 14 and the applying chamber 16 may directly communicate with each other. Further, the manufacturing apparatus may have a structure in which one chamber contains the liquid crystal boat 19, the
25 liquid crystal wiping section 13a and the applying mechanism 13b, and a common heater which heats them is provided.

Next, detailed is a method of manufacturing the liquid crystal display panel 1 which is manufactured by the manufacturing apparatus 10 structured as described above.

5 First, an empty display panel 1a is prepared and carried into the injecting chamber 14. Here, the empty display panel 1a has the first substrate 2 and the second substrate 4 bonded by the sealing member 5, and its liquid crystal intake 7 formed in the sealing
10 member 5 is opened. After the empty display panel 1a is carried, the display panel is injected with liquid crystal in the injecting chamber 14. In this step, first, the evacuating device 21 evacuates the injecting chamber 14 and the display panel 1a disposed in the
15 injecting chamber.

 Then, the liquid crystal intake 7 of the display panel 1a is immersed in liquid crystal put in the liquid crystal boat 19. In this state, the atmosphere in the injecting chamber 14 is gradually returned to
20 atmospheric pressure. Thereby, liquid crystal is injected from the liquid crystal intake 7 into the display panel 1a by using capillary action.

 Further, when the liquid crystal is injected, the heater 18a is operated to heat the atmosphere inside
25 the injecting chamber 14 and maintain the injecting temperature to be not less than a maximum use temperature of the liquid crystal display panel 1 in

the range of its use temperature. The injecting temperature may be a temperature being 5°C less than the maximum use temperature. Here, The maximum use temperature of the liquid crystal display panel 1 is a maximum temperature in the range of temperature at which the liquid crystal display panel is used. In this embodiment, the atmosphere in the injecting chamber 14 is controlled to be $50\pm 5^{\circ}\text{C}$ on the assumption that the maximum use temperature is 50°C .

By heating the inside of the injecting chamber 14 as described above, the display panel 1a into which liquid crystal is to be injected is also heated and maintained at an injecting temperature of $50\pm 5^{\circ}\text{C}$. Further, the liquid crystal to be injected into the display panel 1a is also heated to the injecting temperature simultaneously with injecting, and injected in the thermal-expanded state into the display panel.

By the above step, the area enclosed by the two substrates of the display panel 1a and the sealing member 5 is filled with the expanded liquid crystal, and injection is completed. During the injection, the display panel 1a and the injected liquid crystal are maintained at the injecting temperature. Injecting the liquid crystal in the heated state can reduce the viscosity of the liquid crystal and shorten the injecting time. In the above injecting step, the liquid crystal is heated through the display panel 1a.

However, it is also possible to heat the liquid crystal itself to the injecting temperature, and thereafter inject it into the empty display panel. For example, the liquid crystal being more expanded than the liquid crystal at room temperature may be injected into the display panel.

After completion of liquid crystal injection, the display panel 1a is carried from the injecting device 11 into the carrying chamber 22 of the carrying mechanism 12. The atmosphere in the carrying chamber 22 is maintained in advance at a carrying temperature of $50\pm 5^{\circ}\text{C}$ by the heater 18b. Then, the carrying chamber 22 holding the display panel 1a injected with liquid crystal is carried by the carrier 15 from the injecting device 11 to the sealing device 13, and thereafter the display panel is carried from the carrying chamber into the applying chamber 16.

Thereby, the display panel 1a and the liquid crystal injected therein are sent, in the state maintained at the maximum use temperature after liquid crystal injecting, from the injecting chamber 14 to the applying chamber 16. The atmosphere in the applying chamber 16 is maintained in advance at an applying temperature of $50\pm 5^{\circ}\text{C}$ by the heater 18c. The inside of the applying chamber 16 is maintained at atmospheric pressure, and it is not necessary to apply any specific pressure to the display panel 1a.

Next, the liquid crystal intake 7 of the display panel 1a is closed in the applying chamber 16. In this step, first, the liquid crystal wiping section 13a wipes away excess liquid crystal remaining on the liquid crystal intake 7. Then, the applying mechanism 13b applies a sealant 8 to the liquid crystal intake 7 to close the liquid crystal intake. Since the sealant 8 is applied after wiping away the liquid crystal attached to the liquid crystal intake, excellent application can be performed. Wiping away the liquid crystal as described above produces a space, into which the sealant 8 is took in, in the liquid crystal intake. As the sealant 8, for example, an ultraviolet-curing sealant is used. By the above step, the liquid crystal intake 7 of the display panel 1a is sealed by the sealant 8 in the state where the injected liquid crystal is maintained at the maximum use temperature and thermal-expanded.

After the liquid crystal intake 7 is sealed by the sealant 8, the display panel 1a is moved to the waiting section 13c. Then, the heater 18c changes the atmosphere in the applying chamber 16 from the applying temperature to a waiting temperature of, for example, $55\pm 5^{\circ}\text{C}$. In this state, the display panel 1a is held in the waiting section 13c for a predetermined time to adjust an suction width W of the sealant 8 with respect to the liquid crystal intake 7, as shown in FIG. 4.

Here, The suction width W can be controlled to a desired value by adjusting the waiting temperature, or controlling the viscosity of the liquid crystal injected into the display panel 1a. Although the temperature is changed during the waiting time after the liquid crystal intake 7 is sealed with the sealant in this embodiment, the temperature may have been already changed when the sealant 8 is applied. The step "forming the sealant" in this embodiment includes both application and the waiting time after application.

Supposing that the waiting temperature or the temperature in application is set to 100°C which is 50 °C higher than the injecting temperature, the suction width W of the sealant 8 is 0.0 mm. If the waiting temperature or the temperature in application is equal to or higher than the injecting temperature like this, the liquid crystal in the display panel 1a further expands and pushes the applied sealant 8 out of the liquid crystal intake 7. Therefore, the suction width W is narrowed.

In the meantime, supposing that the waiting temperature or the temperature in application is set to 30°C which is 20°C lower than the injecting temperature, the suction width W of the sealant 8 is 5.0 mm. Specifically, if the waiting temperature or the temperature in application is lower than the injecting temperature, the liquid crystal in the display panel 1a

contracts, and the sealant 8 applied to the liquid crystal intake 7 is taken into the liquid crystal intake 7. Thereby, the suction width W of the sealant 8 is broadened.

5 If the waiting temperature or the temperature in application is controlled within the range of -20°C to $+50^{\circ}\text{C}$ in comparison with the injecting temperature as described above, the suction width W can be adjusted within the range of 0.0 mm to 5.0 mm. The suction
10 width W is preferably controlled within the range of 0.1 mm to 1.0 mm. This is because the first substrate 2 and the second substrate 4 in the vicinity of the liquid crystal intake 7 are provided with a display area for image display, and thus a too broad suction
15 width W has an adverse effect on image display. In this embodiment, the injecting temperature is set to $50\pm 5^{\circ}\text{C}$, and the waiting temperature or the temperature in application is set to $55\pm 5^{\circ}\text{C}$, and thereby the suction width W of the sealant 8 is controlled to
20 0.9 mm. Therefore, the suction width W of the sealant 8 in the liquid crystal intake 7 can be controlled by changing the temperature in injection of the liquid crystal to a temperature in sealing of the liquid crystal intake. The temperature in sealing of the
25 liquid crystal intake 7 is different from the temperature in injection of the liquid crystal.

After the suction width W of the sealant 8 is

controlled, the display panel 1a is carried from the
applying chamber 16 into the curing chamber 17. The
atmosphere in the curing chamber 17 is maintained in
advance at a curing temperature of $55\pm 5^{\circ}\text{C}$ by the heater
5 18d. Specifically, the curing temperature is adjusted
to a temperature equal to the waiting temperature.

Next, in the curing chamber 17, the sealant 8
applied to the liquid crystal intake 7 is cured to seal
the intake. In this step, the ultraviolet irradiating
10 section 13d irradiates the sealant 8 with ultraviolet
rays. This cures the sealant 8 in the state of keeping
the suction width W which has been adjusted in the
waiting section 13c. Thereby, the liquid crystal
intake 7 is sealed, and the liquid crystal display
15 panel 1 injected with the expanded liquid crystal is
finished.

According to the method and the apparatus of
manufacturing the liquid crystal display panel
according to the embodiment of the present invention,
20 structured as described above, the liquid crystal
display panel 1 is formed by injecting liquid crystal
heated to a temperature higher than the maximum use
temperature into the empty display panel 1a and sealing
the liquid crystal intake 7, with the temperature of
25 the liquid crystal in injection maintained. Thereby,
the liquid crystal display panel 1 is held with
thermal-expanded liquid crystal of a proper quantity

corresponding to the volume in the liquid crystal display panel. Therefore, even if the liquid crystal display panel 1 is used at any temperature within the range of the use temperature, the liquid crystal layer is maintained at uniform thickness over the whole liquid crystal display panel, and good display quality is constantly maintained.

For example, if the liquid crystal display panel 1 is used in an environment of the maximum use temperature, each constituent element such as liquid crystal and the columnar spacers 3 expands by heat. However, as described above, the liquid crystal held in the liquid crystal display panel 1 is set to a proper amount in the thermal-expanded state heated to a temperature higher than the maximum use temperature. Therefore, even if the liquid crystal expands in a high temperature environment, no excess liquid crystal exists in the liquid crystal display panel 1, and it is possible to prevent such a defect that the first substrate 2 and the second substrate 4 are deformed by being pressed outward by the expanded liquid crystal. Therefore, the first and second substrates 2 and 4 are constantly kept in contact with the spacers, and the gap between the first and the second substrates is maintained at a predetermined value by the spacers. For example, even if the liquid crystal display panel 1 is vertically stood up, the thickness of the liquid

crystal layer 6 is maintained uniform over the whole liquid crystal display panel, and good image display is possible with display quality retained. Therefore, it is possible to obtain a liquid crystal display panel 1 which prevents occurrence of unevenness in display and maintains good display quality in any temperature within the range of the use temperature.

Further, according to the method of manufacturing a liquid crystal display panel according to the embodiment, when sealing the liquid crystal intake 7, it is unnecessary to discharge excess liquid crystal from the liquid crystal intake by pressing, as performed in the prior art. Therefore, the lead time is shortened and manufacturing efficiency is increased. Simultaneously, waste liquid crystal is reduced, and the efficiency in use of liquid crystal as material is increased.

Further, in the sealing step, the temperatures of the heaters 18c and 18d are controlled within a range of 20°C lower to 50°C higher than the temperature of the panel in the liquid crystal injecting step. Thereby, the suction width W of the sealant 8 is adjusted to an optimum value, and the liquid crystal intake 7 is sealed with reliability.

In the above embodiment, explained is the case where the liquid crystal display panel is manufactured with the maximum use temperature of 50°C. However, the

maximum use temperature is not limited to 50°C, but may be changed to any desired value, for example, 80°C.

Even if the maximum use temperature is set to 80°C, the injecting step, the applying step and the sealing step
5 can be performed in the same manner as the above.

However, the maximum use temperature is preferably set to be equal to or higher than the boiling point of liquid crystal.

In the above embodiment, the injecting temperature,
10 the carrying temperature and the applying temperature are set to the maximum use temperature $\pm 5^{\circ}\text{C}$. Further, the carrying temperature and the applying temperature are preferably the same as or higher than the injecting temperature.

15 Also with respect to other points, the present invention is not limited to the above embodiment, but can be variously modified within the scope of the invention. For example, as shown in FIG. 5, the manufacturing apparatus 10 may be formed by directly
20 connecting the injecting device 11 with the sealing device 13 such that they communicate with each other. According to this structure, a carrying mechanism between the injecting device 11 and the sealing device 13 can be omitted, and the manufacturing apparatus 10
25 is miniaturized. Further, when the display panel 1a is carried from the injecting device into the sealing device, this structure prevents decrease in the

temperature of the injected liquid crystal, and shortens the lead time.

In the above manufacturing apparatus 10 of FIG. 5, the other structures thereof are the same as those in the above embodiment. Like constituent elements are denoted by like reference numerals, and detailed explanations thereof are omitted.

Further, the sealant 8 is not limited to ultraviolet-curing materials, but can be selected according to circumstances. Various means for curing the sealant 8 can be selected according to the adopted sealant.

Wiping of the liquid crystal may be performed with the liquid crystal being more expanded than the liquid crystal at room temperature. The suction width of the sealant in the intake may be controlled by changing an expanded state of the liquid crystal in injection of the liquid crystal to an expanded state of the liquid crystal in sealing of the intake. The liquid crystal in sealing of the intake may be more expanded than the liquid crystal in injection of the liquid crystal.

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WHAT IS CLAIMED IS:

1. A method of manufacturing a liquid crystal display panel, comprising:

5 bonding a pair of substrates to each other with a gap maintained therebetween, and defining an intake between the substrates;

 injecting liquid crystal into a space between the substrates through the intake in an environment heated in comparison with room temperature; and

10 sealing the intake by a sealant, with the environment kept heated from the injecting of the liquid crystal, in which the suction width of the sealant in the intake is controlled by increasing the temperature for sealing compared to the temperature for
15 the injecting of the liquid crystal.

2. A method according to claim 1, further comprising:

 wiping away a liquid crystal adhering to the intake after the injecting of the liquid crystal,

20 wherein

 the wiping of the liquid crystal is performed in an environment heated in comparison with room temperature.

3. A method according to claim 1, wherein

25 the sealing of the intake is performed under atmospheric pressure.

4. A method of manufacturing a liquid crystal

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display panel, the method comprising:

bonding a pair of substrates to each other with a gap maintained therebetween, and defining an intake between the substrates;

5 injecting liquid crystal into a space between the substrates through the intake, the liquid crystal being more expanded than the liquid crystal at room temperature; and

 sealing the intake by a sealant, with the liquid
10 crystal kept expanded from the injecting of the liquid crystal, wherein the suction width of the sealant in the intake is controlled by increasing an expanded state of the liquid crystal in the injecting of the liquid crystal to a more expanded state in the sealing
15 of the intake.

 5. A method according to claim 4, further comprising:

 wiping away a liquid crystal adhering to the intake after the injecting of the liquid crystal,

20 wherein

 the wiping of the liquid crystal is performed with the liquid crystal being more expanded than the liquid crystal at room temperature.

 6. A method according to claim 4, wherein

25 the sealing of the intake is performed under atmospheric pressure.

 7. A liquid crystal display panel manufacturing

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apparatus comprising:

a liquid crystal injecting chamber having a first heater and a liquid crystal boat to inject liquid crystal into a space between a pair of substrates; and

5 an applying chamber which communicates with the liquid crystal injecting chamber and has an applying mechanism which applies a sealant to the pair of substrates and a second heater.

8. A liquid crystal display panel manufacturing
10 apparatus according to claim 7, further comprising:

a carrying mechanism having a third heater,
wherein

the liquid crystal injecting chamber and the
applying chamber communicate with each other, with the
15 carrying mechanism interposed therebetween.

9. A liquid crystal display panel manufacturing
apparatus according to claim 7, wherein

the applying chamber has a liquid crystal wiping
section, and

20 the liquid crystal wiping section is provided
between the liquid crystal injecting chamber and the
applying mechanism.