Liquid Crystal Drop and Vacuum Assembling System for Large Size Substrates

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ABSTRACT

A new liquid crystal drop and vacuum assembling system for large size substrates has been developed.

In the conventional cell assembling process, a color filter substrate and a thin film transistor substrate are positioned with high accuracy and assembled. After that, liquid crystal is filled into the cell using capillary phenomenon of liquid. Disadvantage of this process is extremely long liquid crystal filling time. For this reason, it was difficult to expand panel size and also mother substrate glass size.

In our system, liquid crystal is dropped directly on the substrate in the matrix form controlling each droplet weight, and the substrate with liquid crystal is aligned and assembled with the other substrate in the vacuum environment. By using direct drop method, both LC injection time and lead-time of cell process are reduced, and manufacturing of large size substrate with multi-cell panel become possible. This process is already applied to production of fifth generation glass size and contributes to reduction of cost and time.[1),2)] This process is considered as standard process for large glass substrate.

INTRODUCTION

Production of the LCD panel had been increased mainly for personal computer use. Now, it is taking place of CRT and is also opening up new monitor market by taking advantage of its features including higher accuracy, lighter in weight, space saving, lower power consumption and in addition, by setting remarkably lower price level than usual price down trend. LCD panel production is already more than one trillion-yen industry. Mean time, it is expected to enter into TV market on a full scale by realizing high-speed response and lower price required.

In history, color TV had widely spread by development of the transistor as momentum. Likewise, to expand LCD TV market, it is required to improve production process of LCD using new liquid crystal drop and vacuum assembly system.

The size of standard liquid crystal display panel for the personal computer is 15 to 20 inches. However, its size for liquid crystal TV is 30 to 40 inches, or will be larger than that.

Cell assembly process in the LCD panel assembly, one of the back-end processes in the LCD panel production, is to position and assemble the thin film transistor substrate and the color filter substrate with extremely high accuracy, and then to fill liquid crystal into that panel cell. For larger size LCD panel, this filling process is the bottleneck of the whole production process. This conventional filling process requires about 10 hours in all for 10-inch size panel, 2 hours for vacuum pumping and 8 hours for filling. That makes one hour per one inch. In this way, this process effected to productivity as the panel size went larger.

To raise the production efficiency of the LCD panel, the size of the glass substrate (mother substrate) went on increasing. LCD panel production was started at 300 x 400 mm size (the first generation). The size went on increasing as the need for production efficiency went higher. At 5th generation, the size is about 1 meter square. At 6th generation it will be about 1.5 meter square and at 7th about 2-meter square.

To reduce the filling process time, from the beginning, it had been proposed to drop liquid crystal on one of substrates, then to position and assemble this with the other substrate. However this proposal has not been realized for larger size substrate, as it had a problem in supporting the substrate in the vacuum environment. To solve this problem, we worked out new supporting method using electrostatic adsorption phenomenon, and developed the prototype machines and verification machines for the 5th generation substrates, which big demands for and high efficiency production with are expected. After the process technique has been established, we obtained orders for the liquid crystal drop and vacuum assembling production system lines including plural numbers of assembly machines.

This report is for the new liquid crystal drop and vacuum assembly system that renovated conventional assembly system completely.

LIQUID CRYSTAL DROP AND ASSEMBLING PROCESS

The conventional process can be briefed as below.

To obtain proper spacing between substrates, spacers will be sprayed on the TFT (thin film transistor) substrate, or pillars will be made with photolithography. Sealant will be coated on the CF (color filter) substrate and precured. These two substrates will be assembled and bonded with pressure temporarily, then to cure sealant, thermocompressing bonding will be performed. The substrate will be cut with crib and break system, cleaned and sent to the liquid crystal filling process.

Liquid crystal filling process can be briefed as below; After pretreatment process to purge panel in hot or nitrogen environment, the substrate will be transferred to the buffer chamber and inside air will be pumped out. Then the substrate will be placed with its liquid crystal inlet port on the liquid crystal tray in the liquid crystal filling chamber. By opening this chamber to the atmosphere or by pressurizing the chamber, the panel will be filled with liquid crystal by capillary phenomenon. The inlet port will be sealed with ultraviolet resin, and extra liquid crystal attached around the port will be cleaned. The substrate will be transferred to breadboard mounting process after chamfering, cleaning and attaching polarizing film on it.

Figure 1 shows new process flows for cell assembly.

The new process can be briefed as below;

The liquid crystal will be directly dropped on the TFT substrate with sprayed spacers or pillars made with photolithography. Sealant will be dispensed on the CF substrate. Both substrates will be transferred to the vacuum assembly device. The device will be vacuum by pumping the air out. The CF substrate and the TFT substrate located one on the other will be positioned in the vacuum environment and assembled. The assembled substrates will be transferred after having temporarily fastened by pressing and precuring with ultraviolet light irradiation system on some part of sealant to protect from shifting. The sealant will be cured in curing oven. The substrate will be transferred to breadboard mounting process after chamfering, cleaning and attaching polarizing film on it.

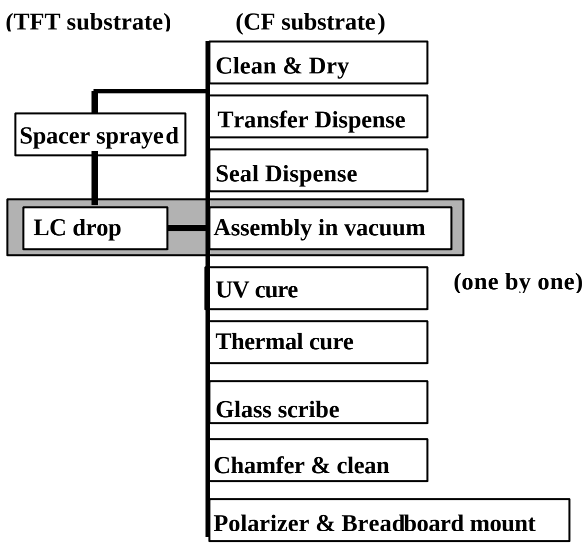

Figure 1. New Process Flow for Cell Assembly

Features of new process against conventional process are;

① Reduction of liquid crystal filling time for LC panel of larger size, narrower gap and with high-viscosity liquid crystal.

② Improvement of utilization efficiency of expensive liquid crystal.

③ Precise supply of liquid crystal to the substrate.

④ Simplification of liquid crystal filling process, and reduction of installation space for the system.

⑤ Accurate assembling by minimizing heating expansion.

⑥ Minimizing production lead-time.

Assembling in vacuum environment had been proposed at early stage of LC panel development, and technical development of this process for small size substrate had been carried out. However, due to two technical problems, ① difficulty in supporting substrates at upper and lower positions when positioning in vacuum environment, ② liquid crystal is liable to be contaminated with sealant as uncured sealant contacts with liquid crystal at positioning, this process had not widely prevailed.

However, by developing proper sealant, later problem can be solved, and that goods results can be expected on panel production.[3]

CONSTRUCTION AND MOVEMENT OF VACUUM ASSEMBLING SYSTEM

The vacuum assembly system is the device to position the substrate with dispensed sealant at one side and the substrate with dropped liquid crystal at the other side in vacuum environment, and assembles them by pressure bonding at atmospheric pressure. We will describe construction and movement of vacuum assembly system, as this is the core device of the “liquid crystal drop and vacuum assembly system”.

Figure 2 shows external appearance photograph of 5^{th} generation vacuum assembly system. Figure 3 shows its construction sketch. The device consists of the vacuum chamber, the X Yθ stage to position the lower substrate table with extremely high accuracy, the up and down drive for upper substrate table, vision cameras for substrate marks and UV light irradiation lamps. The chamber includes the

Figure 2 Vacuum Assembly System

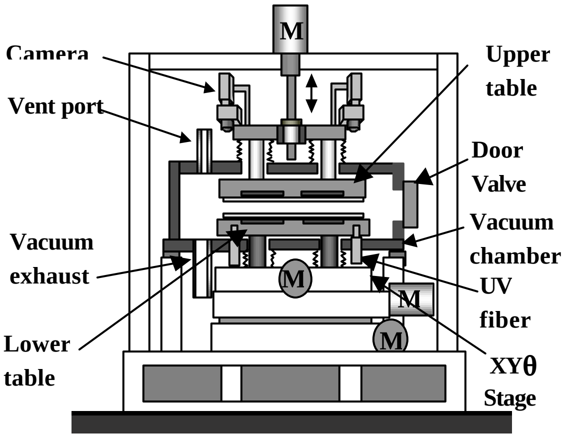

Figure 3. Construction of Vacuum Assembly System

built-in upper substrate table, the built-in lower substrate table and the substrate support craws.

The upper and lower substrate tables have vacuum holes and electrostatic chucks for supporting substrates.

The driving mechanisms located outside of the vacuum chamber will drive the movable units in the chamber. The vacuum isolation mechanisms including the vacuum bellows will isolate inside of the vacuum chamber from outside.

To perform high accuracy assembling, it is essential to keep two substrate tables accurately in parallel positions. Both substrate tables are supported with five rigid support legs to obtain high rigidity. For easy parallel adjustment, upper table up / down driver is equipped with four axes auxiliary shafts.

Movements of the device are as below;

(1) Feed and support of upper substrate

The CF substrate will be reversed upside down and sealant will be on the bottom surface of the substrate. The robot arms will hold the substrate at sealing side of the substrate where mechanical contact is allowable, and transfer the substrate into the vacuum chamber through the door valve. The upper table will be lowered on the substrate and hold it with vacuum and then with electrostatic chucks to support at vacuum environment.

(2) Mark detection of the upper substrate and fine positioning through the vision cameras

The vacuum assembly system has two mark recognition vision cameras for rough positioning and four mark recognition vision cameras for fine adjustment. All these cameras are movable to orthogonal axes (XYZ) directions.

At first, the vision cameras for rough positioning will detect the recognition marks on the upper substrate and move each camera to get the recognition mark at its center of the view. The vision cameras for fine adjustment, as their views are narrow, will receive mark location information from the rough positioning cameras and move and adjust each camera position to get each fine adjustment recognition mark at the center of each view.

(3) Feed and support of lower substrate

The robot arms will hold and transfer the TFT substrate into the vacuum chamber through the door valve. The substrate support craws will move to positions and raise the substrate a little, then the robot arms will move out of the chamber. The claws will lower the substrate on the lower table. The lower table will hold it with vacuum and then with electrostatic chucks to support at vacuum environment.

(4) Vacuum pumping and holding substrates with electrostatic chucks

The door valve of the chamber will be closed. The vacuum pump will pump the air out to lower the pressure to the specified value. The upper table will be lowered to proper height for positioning.

(5) Positioning of the upper and lower substrates with vision

Each vision camera for fine adjustment will detect difference or shift of each detection mark location between two substrates. The X Yθ stage will move the lower table and adjust the lower substrate position accurately to the upper substrate by getting each and every corresponding marks at same locations.

(6) Assembling substrates and precuring

The upper table will be lowered to press the upper substrate to the lower substrate at the specified pressure. The sealant on bottom surface of upper substrate will be crushed to keep vacuum inside or to contain liquid crystal in the substrates. To protect substrates from shift, sealant will be partially pressed and precured by UV light irradiation.

(7) Obtaining specified spacing

After positioning, assembling and temporarily fastening have been done, the chamber will be opened to atmosphere. The atmospheric pressure will uniformly press the assembled substrates and the spacing between plates will be the distance of the diameter of the sprayed spacers or the distance determined by the amount of dropped liquid crystal.

(8) Unloading substrate

The upper and lower substrates may shift their relative location due to bending when transferred. To protect the substrate from this shift, when lifting the substrates with craws at substrate edges, the parallel crosses mechanism in the lower electrostatic chuck will lift the center of the substrate at the same time. The robot arm will unload the substrates in a way to restrict their bending.

LAYOUT OF LIQUID CRYSTAL DROP AND VACUUM ASSEMBLING PROCESS

Figure 4 shows basic layout of the typical liquid crystal drop and vacuum assembling process. This system consists of four liquid crystal drop dispensers, two dotting dispensers for conductive paste, four dispensers for dispensing sealant, two positioning / reversing devices, four vacuum assembling devices, two ultraviolet light irradiation system and clean robots and transfer system between these machines.

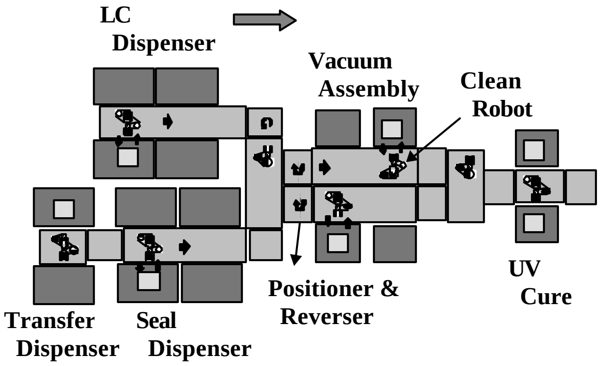

Figure 4 Layout for LC drop and Vacuum Assembly Process

The dispensers will draw the sealant and dot the conductive paste on the CF substrate, and then the transfer robot will send the substrate to positioning / reversing device. Likewise, the dispenser will drop liquid crystal on the TFT substrate, then the transfer robot will send the substrate to the positioning / reversing device. The positioning / reversing device will adjust the position of the substrate and turn the CF substrate upside down. The double arms robot in front of the vacuum assembly device will hold the reversed CF substrate on the lower arm, and TFT substrate on the upper arm. Then the double arm robot will move to the vacuum assembly device when assembly in that device has been done. At first, the robot will transfer CF substrate into the vacuum chamber under the upper table. The upper table will hold the CF substrate with vacuum chuck and then with electrostatic chuck. Then, the lower arm will hold the assembled substrate in the chamber. At last, the robot will place the TFT substrate on the lower table in the chamber.

The vacuum assembly device will close the door valve of the chamber and start assembling of the substrates.

The double arm robot will transfer the assembled substrate to the buffer station.

The ultraviolet light irradiation system located at last stage of the line will cure the sealant in the assembled substrates by irradiating the UV light from CF substrate side.

FEATURES OF LIQUID CRYSTAL DROP AND VACUUM ASSEMBLY PROCESS

Technical merits of this process can be summarized as below;

(1) This process is suitable for cell assembly of high viscosity liquid crystal and large size narrow gap panel for wide view angle, large screen, and high-speed response LCD panel.

(2) This process will sharply reduce the filling time of liquid crystal. It took about 20 hours for 20-inch panel by conventional process. It requires only 4 minutes or under to drop liquid crystal for the same case by this process.

(3) Panels will be made in single-substrate processing. Lead-time will be remarkably reduced. Therefore, the occurrence of defective substrates in a mass scale can be prevented.

(4) Many liquid crystal filling machines in conventional process line will be replaced with few liquid crystal dispensers in this process. Further, the sealing machines, used to seal the liquid crystal filling port, will not be required, and cleaning devices may be reduced. Thus, installation space for the line will be considerably reduced.

(5) The amount of liquid crystal filled in the substrate can be accurately controlled, and its utilization efficiency will be improved. Assumed yield of liquid crystal for the conventional process is about 50%. Expected yield in this process will be approximately 90 to 95%.

(6) Ultraviolet and heat curing resin will be used as sealant. This will reduce the possibility of shift between substrates due to heat expansion.

CONCLUSION

Results of liquid crystal drop and vacuum assembly system for 5th generation LC panel mass production line shows that this process is taking place of conventional process and will be the standard process for cell assembly.

This process also shows possibility of assembling 6th and 7th generation mother glasses without cutting into pieces.

To establish this system as an excellent process machine suitable for the LC panel ever enlarging in size and lowering in price, and to take place of the conventional process that has experienced technique established through past ten years or more, we need to perform further technical development research under close cooperation with panel manufacturers, material manufacturers including for liquid crystal, sealant, glasses, and device manufacturers including for ultraviolet light irradiation system and furnace.

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