One Drop Filling for Liquid Crystal Display Panel Produced from Larger-sized Mother Glass

Akira Hirai
Isao Abe
Masaru Mitsumoto
Shigeru Ishida

OVERVIEW: A cell-assembly line for liquid-crystal panels is a process for fitting together two glass substrates (i.e. a TFT substrate mounting the drive circuit for the liquid-crystal display and a CF substrate for displaying colors) in an arrangement that liquid-crystal material is filled between the substrates. A liquid-crystal vacuum filling system accomplishes "dropping method" — namely, a method in which liquid-crystal material is dropped directly onto one of the substrates, which is then aligned with the other substrate (with sealant dispensed on it) and bonded to it under vacuum. In this way, the weak point associated with the LCD injection method (that is, liquid-crystal injection requires a long time) is eliminated and lead time of cell process is significantly shortened, thereby opening up the way to expand the size of liquid-crystal panels. Hitachi Plant Technologies, Ltd. is providing manufacturing equipment with productivity that fits the needs of particular generations in accordance with the expanding market for liquid-crystal panels — which is succeeding lap-top PCs, monitors, and TVs.

INTRODUCTION

AS a medium for conveying a broad range of information by mobile phones, PDAs (personal digital assistants), games, lap-top computers, liquid-crystal monitors, and liquid-crystal TVs (televisions), liquid-crystal panels — whose practical application started in calculators and watches — are creating new applications while their market continues to expand. In particular, liquid-crystal TVs are continuing to replace CRT (cathode-ray-tube) TVs because they not only take advantage of the basic characteristics of liquid crystals themselves (i.e. compactness, lightness in weight, and low power consumption) but also realize higher resolution, wider viewing angle and high-speed response (which has been a weak point of conventional liquid crystals). Furthermore, the popularization of liquid-crystal TVs is being spurred on by the facts that the provision of high-quality content is becoming widespread, various countries (e.g. Holland and Sweden) have completely switched over to digital terrestrial broadcasting, and the changeover period for many other countries is drawing near.

Through practical application of the LC (liquid crystal) dropping method called ODF (one-drop filling)[1], which aligns, assembles, and pastes together under vacuum a CF (color filter) substrate and a TFT (thin film transistor) substrate (in such a condition that liquid-crystal material is then "dropped" onto one of

Sealant-dispensing unit

Vacuum-assembling unit

Fig. 1—Sealant-dispensing Unit and Vacuum-assembling Unit Composing Liquid-crystal Vacuum-filling System.
Hitachi Plant Technologies, Ltd. is providing a sealant-dispensing unit and a vacuum-assembling unit composing a vacuum-filling system for handling growth in size of liquid-crystal panels.

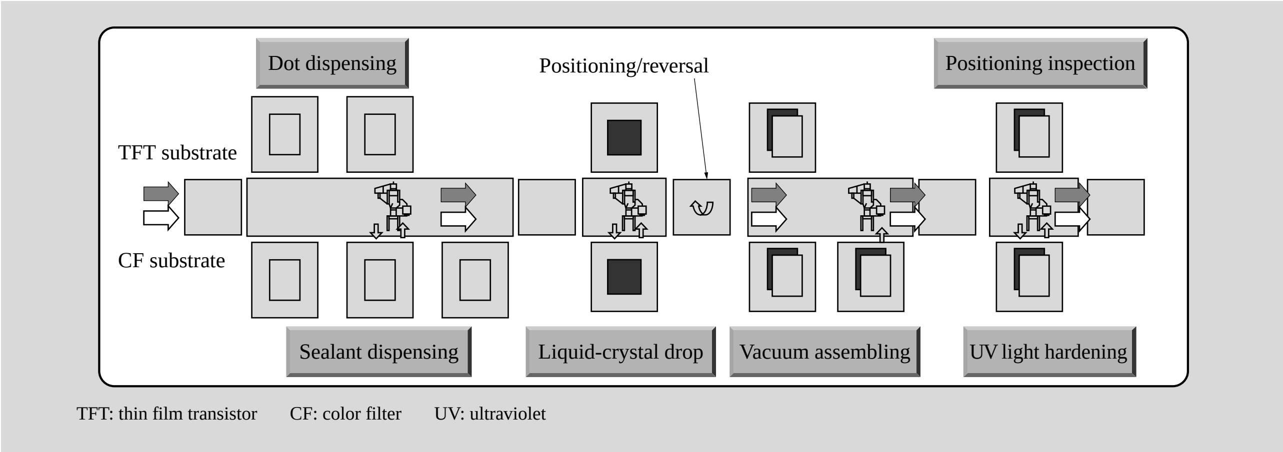

Fig. 2—Line Configuration of Cell-assembly Process.
The cell assembly process consists of apparatuses for sealant dispensing, dot dispensing, liquid-crystal drop, vacuum assembling, UV light hardening, and position inspection as well as transfer units such as robots and positioning and transfer units.

the substrates), Hitachi Plant Technologies, Ltd. is eliminating the main weak point of the LC injection method (which has been a major barrier to expanding the size of liquid-crystal panels) and paving the way towards scaling up liquid-crystal displays.

The popularization rate of large-scale liquid-crystal TVs is, however, quickening; consequently, it is said that further reduction in set pricing is necessary, and each panel manufacturer is continuing technical development and capital investment aimed at that target.

In the rest of this report, as part of the liquid-crystal vacuum filling system for handling mother glass (which is getting bigger and bigger), a sealant-dispensing unit and a vacuum-assembling unit, which constitute the cell assembly process, are described (see Figs. 1 and 2).

NEEDS REGARDING LARGE LCD PANELS

The mother glass for producing liquid-crystal panels comes in predetermined sizes in such a way that six or eight panels can be manufactured simultaneously for the sake of manufacturing efficiency. The sixth-generation of glass substrates has a dimension of 1,800 × 1,500 mm, from which eight 32-inch panels can be taken off. (Note that the glass dimensions stated here are given as representative examples.) At present 30- to 32-inch liquid-crystal TVs are the most popular. Compared to conventional CRT TVs, liquid-crystal TVs take up less space thanks to their thin, flat screens. Moreover, since the optimum viewing distance is three times the height of the screen, a big screen can be enjoyed without feeling any sensation of oppression even if the screen size is scaled up compared to a conventional TV size. Moreover, “wide” sizes of screens with a 16:9 horizontal-to-vertical ratio have become popular, and the hot-selling items are continuing to shift to 40-inch and even bigger sizes. Accompanying this shift is the scaling up of the mother glass to the seventh-generation size (1,870 × 2,200 mm), yielding eight 40-inch panels, and on to the eighth-generation size (2,200 × 2,500 mm), yielding eight 47-inch panels.

As the mother-glass size has been scaled up, the fabrication equipment that constitutes the cell-assembly process has also increased in size. With this increase in scale of the fabrication equipment, equipment structural design accounting for delivery constraints and on-site assembly, basic mechanical design considering tact time and accuracy, and maintaining cleanliness and stability become the main challenges.

SEALANT-DISPENSING UNIT

Dispensing-head Moving Type with Good Space Efficiency

The sealant-dispensing unit applies a sealant to one of a pair of glass substrates, where the sealant’s task is to join the upper and lower glass substrates around the periphery of a liquid-crystal panel in the state that a liquid-crystal material fills the interior of the panel. As regards the dropping method, in contrast to the conventional injection method, dispersion is performed so as to form a closed-loop pattern without

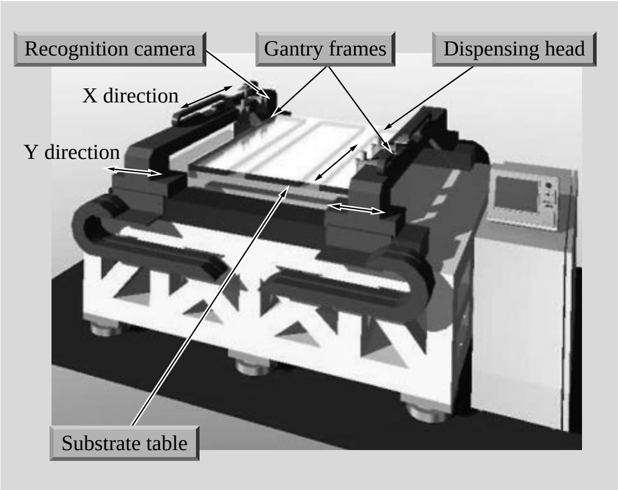

Fig. 3—Basic Structure of Head-moving-type Sealant-dispensing Unit.
The unit is composed of two pairs of gantry frames that travel along the Y direction and multiple dispensing heads (which travel along the X direction in the gantry frame).

an inlet.

Conventionally, dispensing of the sealant is performed while the dispensing head is fixed and the table is moved. However, with this method, space in which the mother glass moves is necessary, and equipment cannot be configured to fit into conveyor-width limitations. As a result, in response to the trend towards large-scale mother glass, systems that have a movable head and a fixed table are being switched over to (see Fig. 3).

The dispensing head is set on the gantry frame and moves in the X direction within the frame. And moving the gantry frame in the Y direction enables a given pattern to be drawn. Moreover, to shorten the dispensing tact time, multiple heads are set up, and their movement in the X direction is controlled simultaneously. The movement of the dispensing enables the multiple heads to be positioned along the same axis of displacement by utilizing a linear motor in place of the conventional ball screws and a servo motor. By executing movement in the Y direction of the gantry frame using linear motor and by setting up the gantry frames as a pair, it is possible to further shorten the tact time and reduce the surface area taken up by the equipment.

Clean Moving-frame Structure

As for a conventional moving-table-type dispenser, the head is moved before dispensing the sealant, and during the dispensing process, the head is pre-fixed. As a result of this setup, contaminant particles are prevented from sticking on the dispensing substrate glass. On the contrary, in the case of the moving-head-type dispenser, the dispensing head and the gantry frame move above the substrate during the dispensing process. Consequently, it has been necessary to take ever more notice of the sticking of particles.

Given those circumstances, by adopting a less-particle cable structure in conjunction with optimizing partial exhaust and improving the configuration of both the dispensing head and gantry frame, it is possible to eliminate the particles on the substrate and, in doing so, attain a thoroughly clean dispensing process and improve the ratio of good quality liquid-crystal panels.

High-speed High-precision Dispensing

The sealant dispenser measures the distance between the dispensing nozzle and the glass substrate at the vicinity dispensing point. This value is then controlled in real-time so that it corresponds at all times with a pre-set value.

In the corners of a panel, the sealant-dispensing rate varies rapidly. Accordingly, in this region, control of dispensing pressure (which is responsible for extruding the sealant) is performed in coordination with the above distance-value control.

Although the time for dispensing sealant increases with the scaling-up of panel size, it is necessary to increase the dispensing speed so that sealant can be dispensed in a shorter time even in the case of larger panels. Accordingly, distance control and control performance of dispensing pressure are further improved, thereby creating high-speed and high-accuracy dispensing of sealant (see Fig. 4).

VACUUM ASSEMBLY UNIT [2],[3]

Stable Holding of Glass Substrate

The vacuum assembly equipment aligns under vacuum the substrate with sealant applied and the substrate with liquid-crystal material dropped onto it by means of an alignment mark set at each corner of each substrate, and after that it pressurizes using atmospheric pressure and bonds the substrates together.

To accomplish bonding of the glass substrates under vacuum, it is necessary to hold the two glass substrates in a particular manner that the upper glass substrate does not touch the lower substrate under vacuum, and after the substrates are positioned, the upper one is assembled and bonded to the lower substrate. Accomplishing this holding and positioning under vacuum makes the dropping method possible, and the

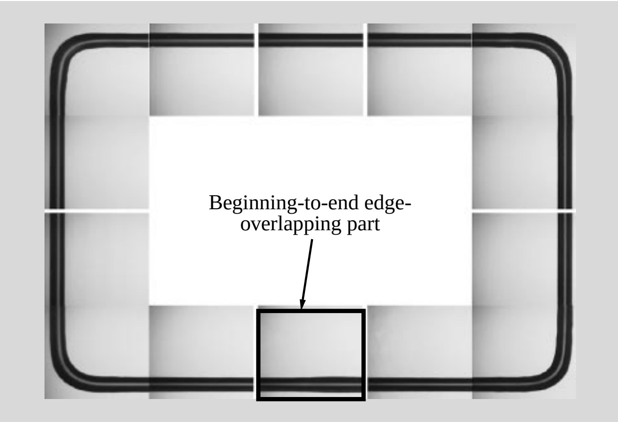

Fig. 4—High-speed Sealant Dispensing.
An example of a closed-loop pattern drawn at dispensing speed of 300 mm/s is shown. High-speed dispensing is performed over an even dispensing sectional area, and a uniform cross section is maintained even if dispensing start point and finishing point overlap.

big problem that comes with scaling up panel size is thus solved.

The first vacuum assembling equipment simultaneously used electrostatic chuck and vacuum suction to hold the glass substrates in place. However, in regard to the bonding of liquid-crystal panels, which get bigger and more diverse all the time, this method suffers problems from the viewpoint of stability and productivity. Given that situation, in parallel with improving the performance of the conventional method, we have developed a new glass-substrate handling technology in place of the electrostatic chuck, namely, a so-called PSC (physical sticky chuck) using a special diazo sticky sheet used for large-size glass substrates.

With the PSC method, a PSC sheet (which maintains a stable adhesive force) and a delamination mechanism (which minimizes the deformation of the substrates after bonding them) is used. This holding mechanism is a multitiered structure for performing so-called “soft chucking,” and even when the glass substrates are scaled up in size, the seal is steadily squeezed under vacuum, and by application of atmospheric pressure after the substrate bonding, it is possible to assure the uniformity of the gap between the substrates.

Chamber Configuration and High-precision Positioning

The vacuum assembly unit consists of two separate (upper and lower) chambers, an upper substrate table and a lower substrate table. It positions the glass substrates under vacuum and then bonds them together. To ensure that no influence is exerted by deformation of the vacuum chamber, the lower substrate table is supported by free joints and legs fixed to a lower base, and it can move in the horizontal direction. Moreover, its movement can be controlled along three horizontal axes (X,Y, and θ) by three drive shafts fixed to the exterior of the chamber. By arranging the drive system on the exterior of the chamber in this way, cleanliness inside the chamber is maintained. And directly driving the stage and adopting the mechanism for positioning the substrates under vacuum enable positioning with good controllability and low hysteresis.

Moreover, by means of a support structure with

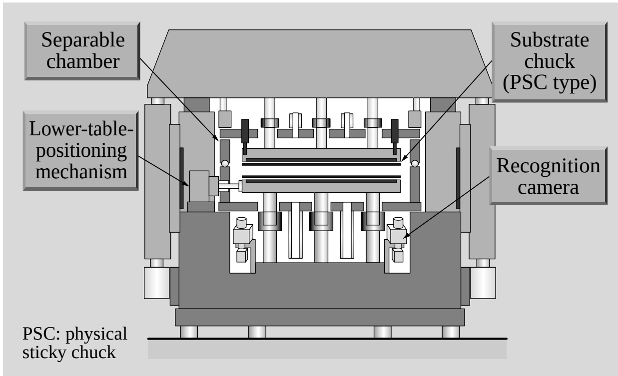

Fig. 5—Basic Configuration of Vacuum Assembling Unit.
Stability and high precision are attained by a mechanism for directly driving a lower table on a free joint and a mechanism for raising a highly rigid upper table.

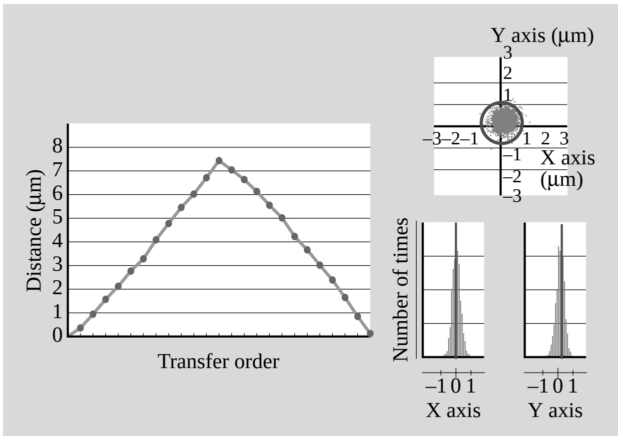

Fig. 6—Transfer Performance of Positioning Mechanism and Positioning Precision of Laminated Panel.
A good linear characteristic with low hysterisis in the positioning mechanism is shown. The right-hand side shows the positioning accuracy of the panel: a sigma-value of less than 0.3 μm and high accuracy can be maintained stably even for a large-scale substrate.

recognition optics that accounts for vibration and high-resolution lenses, it is possible to recognize the glass-substrate position marks with high accuracy. At the same time, by means of a guide mechanism on the side of the chamber, the upper substrate table can move up and down without any horizontal friction, and the bonding after substrate positioning can be performed with high accuracy (see Fig. 5). The positioning and bonding methods described above make it possible to perform the substrate-bonding operation at high accuracy and high speed (see Fig. 6).

On-site Assembly by Block Division

Since the glass substrates are positioned within the chamber, atmospheric pressure is felt from the outside under the condition that there are no support members in the intermediate parts. Although the structure and board thickness are determined so that the chamber suffers no fatigue damage due to atmospheric pressure, as the substrate size is scaled up, not only chamber size but also plate thickness increase, so the weight of the assembly unit exceeds the weight that can be transported.

To handle such increase in weight of the unit, in the case of the eight-generation unit, the main-unit structure is configured so that the upper frame, upper chamber, and upper table are combined as an "upper block" that is separated from the "lower block." Moreover, the upper block can be transported to the actual site in a simple "on-pedestal" condition, and it can be put together in a short time on-site by using a special jig and crane. In this manner, weight restrictions that must be adhered to while the unit is being transported and size limitations on site can be accommodated.

CONCLUSIONS

This report described the development circumstances regarding a liquid-crystal vacuum-filling system for accommodating large-sized glass substrates. Although vacuum-filling systems have become one of the triggers for opening up major markets succeeding LCD monitors and LCD TVs, from now onwards it is thought that flat-panel displays (starting with liquid-crystal displays) will continue to develop as "information windows." While integrating new and conventional technologies and exploiting our experience gained in equipment manufacturing and installation up till now, Hitachi Plant Technologies, Ltd. will continue to contribute to the flat-panel-display industry through technical development firmly focused on the future and development of high-quality equipment.

REFERENCES

(1) H. Kitahara et al., "Technical Innovation in Cell Processing — the Key to Quality and Cost Reduction Concerning Liquid-crystal Displays," FineTech 2006 Seminar (Apr. 2006) in Japanese.

(2) I. Abe et al., "Liquid-crystal Vacuum-filling System," Hitachi Industries Technical Report, No. **4**, pp. 36-42 (2005) in Japanese.

(3) A. Hirai et al., "Liquid-crystal-dropping and Vacuum-bonding Technologies," 2007 LCD Technologies (complete works), *Electronics Journal*, pp. 350-354 (2007) in Japanese.

ABOUT THE AUTHORS

Akira Hirai

Joined Hitachi, Ltd. in 1972, and now works at the Ryugasaki Works, the Electronics Systems Integration Division, the Mechatronics Group, Hitachi Plant Technologies, Ltd. He is currently engaged in the development of manufacturing systems for flat panel displays. Mr. Hirai is a member of The Japan Society of Mechanical Engineers and Japan Welding Society.

Isao Abe

Joined Hitachi Sanki Engineering Co., Ltd. in 1978, and now works at the Ryugasaki Works, the Electronics Systems Integration Division, the Mechatronics Group, Hitachi Plant Technologies, Ltd. He is currently engaged in the development of manufacturing systems for flat panel displays.

Masaru Mitsumoto

Joined Hitachi Sanki Engineering Co., Ltd. in 1980, and now works at the ODF Design Department, the Ryugasaki Works, the Electronics Systems Integration Division, the Mechatronics Group, Hitachi Plant Technologies, Ltd. He is currently engaged in the development of manufacturing systems for flat panel displays.

Shigeru Ishida

Joined Hitachi Sanki Engineering Co., Ltd. in 1984, and now works at the DSP Design Department, the Ryugasaki Works, the Electronics Systems Integration Division, the Mechatronics Group, Hitachi Plant Technologies, Ltd. He is currently engaged in the development of manufacturing systems for flat panel displays. Mr. Ishida is a member of The Japanese Liquid Crystal Society.