Automatic Repair Technology of Fine Pattern in LCD Manufacturing Process

Hiroaki OBA*

NTN has been working on the development of repair technologies to boost the yield of color filters (CF) and thin film transistors (TFT), which are components of liquid crystal displays (LCD). Recently, customer demand for greater productivity in the repair process has increased, and we have developed automatic repair technologies in response.

This paper presents an overview of the automatic repair function used in an LCD repair system. As automatic repair functions, automatic defect detection, repair position calculation, ink color selection and detection of abnormal repairs, for example, are realized by applying image-processing technologies. These functions improve the efficiency of repair processes and meet customer demands for high productivity.

1. Introduction

As the demand for LCD television sets increase, the upsizing of substrates as characterized by the adoption by panel manufacturers of the 10th generation glass substrate with a side over three meters is in progress, while the need for defect repair devices contributing to the improvement of production yield is increasing. NTN has developed and is selling repair devices for color filters that apply ink to defects with a repair needle, while other repair devices cut circuits on TFT substrates with YAG laser to remove defects. They are implemented in a vast number of liquid crystal manufacturing processes.

Of these repair devices, the shortening of tact time and the improvement of repair quality are required. In addition, requirements for efficiency improvement in manufacturing processes and labor saving have increased recently to reduce panel cost. In response to these requirements, NTN has engaged in the development of automatic repair functions that will provide effective labor saving tools.

In the past, the operator who observed the defect state displayed on the monitor chose the machining repair conditions and specified the repair position. NTN developed an image processing algorithm of our own suitable to defects to be repaired, and by using the outcome of this development, NTN realized the automation of defects detection, calculation of repair positions, selection of ink color for the repair, and repair abnormalities detection.

In this paper, after a brief description of the liquid crystal display repair device, the automatic repair function NTN developed will be presented.

2. Liquid crystal display repair device

Fig. 1 shows the appearance of the liquid crystal display repair device. This device consists of a chuck mechanism that fastens the substrate, a repair head that is equipped with a repair function, and an XYZ stage that moves the repair head to the defect position.

* Precision Equipment Division  Product Engineering Department
The repair head is equipped with an optical system to observe defects on substrates, a laser with which patterns are cut and defects are removed, and an ink applying mechanism that applies ink to spots where defects were removed.

Special hardware is not necessary to implement the automatic repair function. Images fit for image processing are captured with a CCD camera by controlling the reflecting light source and the transmission light source, taken into the computer of the repair device and processed arithmetically, and the repair device is controlled in accordance with the results of the image processing; these processes make it possible to allow the automatic repair function to work.

Fig. 2 shows the general flow of automatic repair processes. When a substrate to be repaired is brought into the device, the substrate is chucked and aligned, and the repair head moves to the defect position. The information on the defect position is acquired from the inspection device while the substrate is being carried in position.

After the repair head has been moved to the defect position, the substrate surface is focused on for the defect to be centered. After this, the defect is detected to identify the kind of defect (black defects, white defects, and so forth), and depending on the kind of defect, the repair measure (laser irradiation or ink application) is chosen and implemented.

Furthermore, whether repair abnormalities remain after the repair is checked. When an abnormality is detected such as a remaining defect in a laser-irradiated area or a white defect in an ink-applied area, the buzzer is sounded with the automatic repair work interrupted and the operation is changed over to manual operation by the operator.

When a substrate is judged to be repaired correctly, the repair head is moved to the next defect to repeat identical automatic repair operations, carrying out repair operations on all defects on the substrate.

Processes needing repair operations in liquid crystal manufacturing processes are either so-called upstream ones such as TFT substrates and color filter substrates or downstream processes in which liquid crystals sealed into cells or modules are processed.

Depending on the process introduced, the defect kind and the repair methods vary. In the following, the function of automatically repairing color filter substrates and TFT substrates is described.

### 3. Function of automatically repairing color filter substrates

For this function, a dedicated image processing algorithm was developed that allows (1) the defect detection, (2) the repair position calculation, (3) the correction ink color determination, and (4) the detection of abnormal repair to be processed automatically.

Defects occurring in the color filter are white defects and black defects shown in Fig. 3 (a). A white defect is a result of a missing part of the membrane formed on the substrate and the original RGB colors are missing. A black defect is one characterized by the mixture of colors as a result of the black matrixes membranes swelling out or RGB colors due to defective shapes and other causes. In repairing these defects, the defect is removed by means of laser in the first place regardless of the defect kind, and after this, the part that the defect has been removed is repaired by applying ink on it. In addition, the
3.2 Method of determining repair positions

As described above, in repairing the color filter, a defect is irradiated with laser to remove it first, and then the area that a defect is removed is covered with ink for repairing. For this purpose, it is necessary to determine the laser irradiation position and the ink application position automatically. This function uses the information on the position and size of the defect obtained through the processing of defect detection to determine these positions.

Fig. 4 shows an example of determining the repair position. When the defect is smaller than the circle on which ink is applied as shown in Fig. 4 (a), the repair position is determined so that the ink application center aligns with the defect center. When the defect is larger as shown in Fig. 4 (b), repairing work is divided into several operations to be conducted. The number of repairing operations is determined by the defect size and the size of the circle on which ink is applied.

Actual automatic repair requires a treatment that is equivalent to the repair quality achieved by an operator and is more efficient. For this reason, the algorithm contains ordered steps to minimize damage to the normal region near a defect and the number of times of repair.
3.3 Determination of the repair ink color

In repairing a defect, ink with the normal color area must be applied to the defect; this requires determining the ink color to be applied.

In this treatment, the color information on the same region in the normal image as that in the extracted defect is obtained by means of image processing, and the color information obtained is compared with that which is associated with each ink beforehand to choose an ink having the closest color information.

Using the example of the defect image and the normal image, how to determine the repair ink color is explained below. Suppose, for example, that pieces of color information cR, cG, cB, and cBlk are assigned to four kinds of repair ink R, G, B, and Black (abbreviated as Blk in the following). If, in Fig. 5, the piece of color information on position (b) in the normal image, which corresponds to position (a) in the defect image, is judged as the closest to the color information piece cG, ink G that has the color information piece cG is chosen as the repair ink.

3.4 Detection of repair abnormalities

In repair operations carried out by an operator manually, he or she inspects images visually from time to time in the course of operation to check to see if repair operations are carried out properly. For instance, he or she proceeds with his or her operations visually checking to see if defects remain not removed after laser irradiation and how a defect has been filled with ink after ink application.

This function carries out inspection based on image processing after each automatic laser irradiation and ink application to ensure that repair treatment has been performed properly.

3.4.1 Inspection after laser irradiation

After laser irradiation, the irradiated domain is inspected to make sure that defects are not remaining. Fig. 6 (a) shows an example of remaining defects. Defects such as foreign objects with an elevation may not be removed with single laser irradiation, needing repeated laser irradiation for removal as shown in Fig. 6 (b). However, when laser is used for a long time, a decrease in power may prevent removing defects; therefore, if a defect cannot be removed after a predetermined number of removal operations, it is judged as abnormal.

3.4.2 Inspection after ink application

After the application of ink, the presence of white patches that are not filled with ink, as shown in Fig. 7 (a), and that of areas on which a large quantity of ink is dropped, as shown in Fig. (b), are detected. When the viscosity of ink changes or when the needle cleaning is not enough, such phenomena occur rarely. As in the defects removal by means of laser irradiation, the possibility is high that a desired result is not obtained after the repetition of operations, and such phenomena are judged as abnormal.
4. Function of automatically repairing TFT substrates

Major repair operations on TFT substrates include removing defects by means of laser and cutting part of electrical circuits formed on the substrate. Repair operations include finding breaks in continuous electrical wires on a substrate and also applying metal paste on them with an application needle to restore continuity. Repair operations using laser are divided roughly into the two kinds that follow:

(1) Carrying out repair operations predetermined as needed by defects, such as removing a defect and cutting part of a pattern; and
(2) The operator confirms a defect visually and determines the detail of the repair operation.

Operations falling under category (1) can be automated by combining them with image processing. The repair head is moved to the defect position, and the accurate defect position is detected by image processing, and then the defect is moved to the center of the laser irradiation scope. After this, the result of the repair operation by laser irradiation is checked using image processing.

Operations falling under category (2) are considerably complex. Even if the defect position can be identified by using image processing, repair is not always carried out at that position. For this reason, the operator makes an assessment of the defect state visually and selects the repair method. To address an increase in the time needed for repair operations, a function is needed for the device to carry out automatic repair operations on a defect separately from the operator while he or she is defining the repair details operations for another defect.

In repair operations using an application needle to restore breaks in a group of continuous electrical wires, on the other hand, the inspection device on the previous process is not capable of identifying where on continuous wiring a break has occurred. To address this problem, the repair device is required to be equipped with a function to identify where a break has occurred.

For this function, too, the algorithm has been developed with the aim of minimizing operations carried out by the operator so that this function may contribute to reducing repair operation time and labor. In addition to flat panel displays, this inspection algorithm can be applied to uses aiming at trimming.

4.1 Automatic removal of defects by means of laser

The following are automatic repair steps to remove defects such as foreign objects adhering to a pattern.

(1) The head is moved to the defect position detected by the inspection device on the previous process;
(2) The defect position displayed on the monitor is detected by a method suitable for the defect in question such as the method described in Subsection 3.1 and the comparison of repeated adjoining patterns, and is moved to the center of the screen again (Fig. 8).
(3) The scope of laser irradiation is changed to the specified size or the one equivalent to the defect and the defect is irradiated by laser. The machining conditions such as laser power and oscillation frequency are registered in the device in advance.
(4) The result of repair is checked by the method equivalent to that described in Subsection 3.4.1 or comparing images before irradiation with ones after irradiation; if no defects are left, the workpiece is judged as normal. If part of defects is found remaining, they are irradiated by laser again. If defects remain after the repetition of the specified times of laser irradiation, the workpiece is judged as abnormal.

![Fig. 8 Centering of defect](image)

4.2 Automatic cutting of a specified position

The steps of automatic repair operations by which a specified position on a pattern is irradiated with laser to form a redundant circuit and similar purposes are shown below:

(1) The head is moved to the defect position detected by the inspection device on the previous process;
(2) The region to be cut by means of laser irradiation is detected from among the patterns displayed on the monitor by image processing such as pattern matching, and moved to the center of the screen...
4.3 Automatic defect tracking and repair of continuous wiring

Automatic repair operations are applicable also to a break and a short-circuited part of continuous wiring shown in Fig. 10.

These defects are detected by electric inspection, but the inspection device in the previous process gives the information on the number of the wire in which a defect exists, not the information on the abnormal point coordinates.

For this reason, in manual repair operations by the operator, the repair head was moved to the start of the wiring, from which the operator moved the repair head along the wiring with a tool such as a joystick while following the head visually to identify a default. However, this method took a great many hours to identify a defect, which necessitated the development of an automatic repair function.

Fig. 11 shows how this automatic repair function follows a defect. Tracking starts from screen A. The repair device acquires the number of the line marked with a black circle in screen A. The coordinates of the black circle are calculated from the pieces of design information such as the line number and line-to-line pitches. The design information is registered in the device in advance.

With the head starting from A and moving from stage to stage in order of A, B, and C, image data is captured in sequence, and the defect is detected after the binarization processing and comparison with the adjoining patterns. When a defect is detected, the stage is stopped there and repair operations suitable to the defect are conducted automatically. Fig. 11 shows a straight-line-like pattern; however, tracking can also be performed on a pattern that twists midway.

When a defect is a break in wiring, metal paste is applied to the broken part with an application needle to recover continuity. When a defect is a short circuit, it is irradiated with laser to be removed for repair.
5. Conclusion

This paper presented the automatic function of the liquid crystal display repair device.

The flat panel display market will continue widening, with the screen becoming larger and finer. This will, it is anticipated, require repair devices to be capable of repairing more defects efficiently and with good quality, while requirements for shorter tact times and labor saving becoming still stronger.

Aiming at the development of repair devices capable of responding to new requirements from manufacturing processes and contributing to the improvement of the yield of flat panel displays, we will continue making an effort to enhance functions of the repair device.

References


Photo of author

Hiroaki OBA
Precision Equipment Division
Product Engineering Department