In-line Automatic defect inspection and repair method for TFT-LCD production

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Abstract

We have developed an automated circuit defect inspection and repair method that can be used to improve the yield ratio of TFT-LCD. The method focuses on correcting resist patterns after the development process to ensure shape regularity. We built a prototype system and confirmed that the method is valid.

1. Introduction

In the manufacturing process of TFT substrates for liquid crystal panels, foreign objects can cause circuit defects and partial pixel working errors. Therefore, repair technology for circuit defects is indispensable for improving the productivity of TFT substrates.

Figure 1 shows the pixel structure of TFT substrate for liquid crstal panel. In figure 1, the short defect exists on a-Si island makes the drain and the source short cicuit. Therefore TFT doesn't work proper function. Meanwhile, the open defect exists on the drain line.

Conventional inspection and repair methods have been adaptable only for metal materials, not for passivation and amorphous silicon [1][2]. A perfect circuit defect repair system has not been developed. In addition, conventional methods have required the development of a new recipe for each kind of circuit metal material. Furthermore, repair work has not been automated.

We have developed an automated circuit defect inspection and repair method that can be used independently of the circuit materials. We focused on the resist patterns on the circuit material layer of TFT substrates before the etching process, and developed the method for short defect; the major defects of resist patterns[3]. In addition, we developed the open defect repair method. We developed a prototype system for TFT substrates based on our research, which enables to repair open and short defect, and confirmed that the system worked automatically.

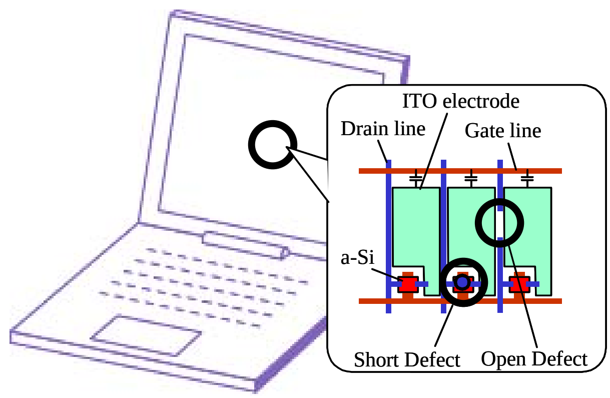


Fig. 1. Pixel structure and defects of TFT.

2. Principles of the pattern defect inspection and repair procedures

Figure 2 compares the proposed resist pattern defect inspection and repair system to conventional systems. Circuit defect inspections were performed with the latter following thin-film deposition, exposure, and etching. Repairs were made based on the results of inspection. Such systems are required to finetune inspection and repair parameters for each circuit material.

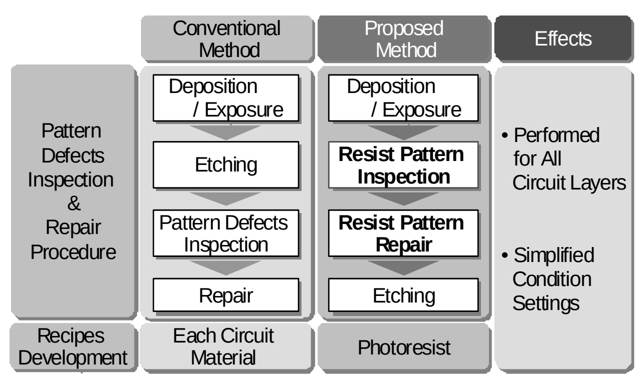


Fig.2. Comparison of Pattern Defect Inspection & Repair Procedures

In contrast, the pattern defect inspection and repair system described here performs defect inspection after the steps of thin-film deposition and exposure. Abnormal resist patterns detected by the system are repaired at this point and then etching is performed, an order which allows the system to inspect and repair the whole layer, independent of the circuit metal material. Since the inspection and repair parameters depend only on the resist type, the suitable inspection conditions are much easier to determine and set.

First we tried the open defect repair method with a dispenser. Figure 3 gives the results of partial resist coat with a dispenser unit. The diameter of resist was approximately 200μm. Therefore the resist dispenser unit enables the good repair of the open defect.

Then we investigated the wavelength absorption characteristics of the resist patterns used in TFT liquid crystal panels. The absorption characteristics of a positive-type resist material indicate that the absorbance of the resist displays a peak near 300 nm.

Figure 4 gives the results of fine patterning for resist thin films and metal film using a YAG laser. The results for resist film patterning performed with FHG yielded good consistency between the laser irradiation pattern and resist patterning and high patterning precision. In contrast, with THG, debris scattering and carbonization were observed near the area of laser irradiation.

The patterning precision was also relatively poor compared with FHG. The results of metal thin-film patterning using FHG show that five fold greater patterning energy was required for metal patterning than for resist thin films. Additionally, more debris resulted, and patterning precision was lower. Based on these results, we concluded that fine patterning of resist thin films with FHG offered advantages in patterning energy and precision.

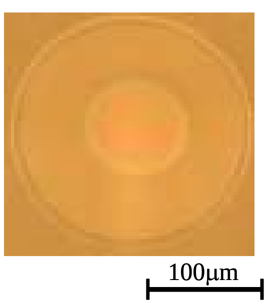


Fig.3. Dipensed Photoresist

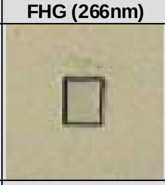
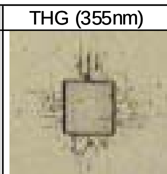
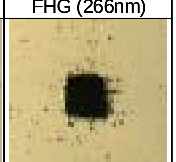
	Photoresist Film		Metal Film
Wavelength	**FHG (266nm)**	THG (355nm)	FHG (266nm)
Patterning Condition			
Patterning Energy	1	–	5
Debris	Excellent	Poor	Poor
Pattern Precision	Excellent	Good	Poor
Others	–	Film Carbonization: Poor	Patterning Burrs: Poor

Fig.4. Comparison of Photoresist Patterns

3. Proposed system configuretion and function of inspeciton and repair system

Figure5 shows the configuration of the resist pattern defect inspection and repair system. The basic concept of this inspection and repair system is to perform the inspection and repair inline by linking the system directly to the photolithographic process line.

The system consists of a resist pattern defect inspection system and a pattern repair system. The first system photographs the resist pattern formed on a glass substrate using inspec-tion cameras, storing the resulting image data on a PC. The PC then analyzes these images by com-paring adjacent pixels to detect

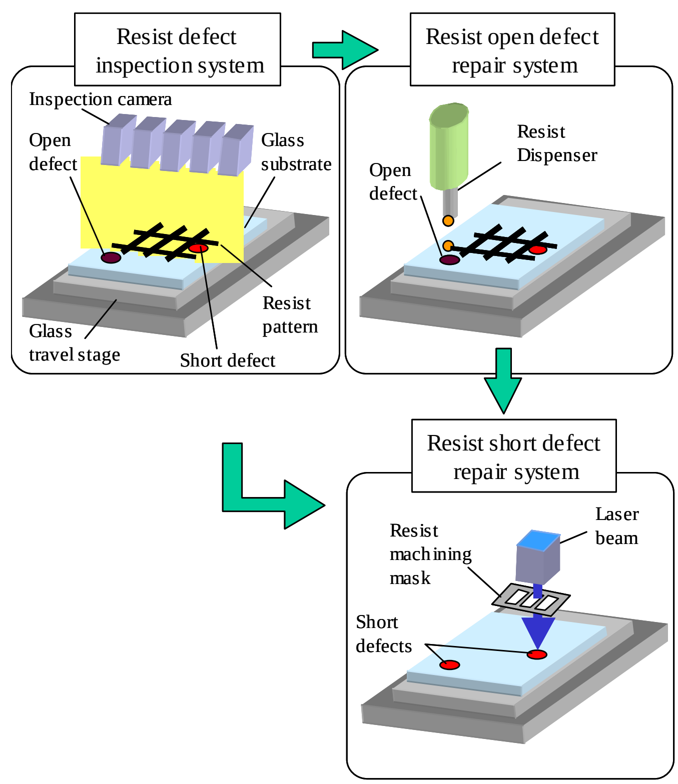


Fig.5. Resist defect inspection and repair system

abnormal resist patterns. The coordinates and images of the defective regions are sent to the resist pattern repair system. The open defect repair apparatus is equipped with a resist dispenser. The short defect repair apparatus incorporates a laser unit with a resist ablation mask (partial exposure mask) with the regular circuit pattern. The short defect repair apparatus uses a resist ablation method to remove excessive resist. In accordance with the defect information, the laser repair apparatus moves and aligns the laser unit and resist ablation mask at the defect coordination, and fires the laser beam through a resist ablation mask.

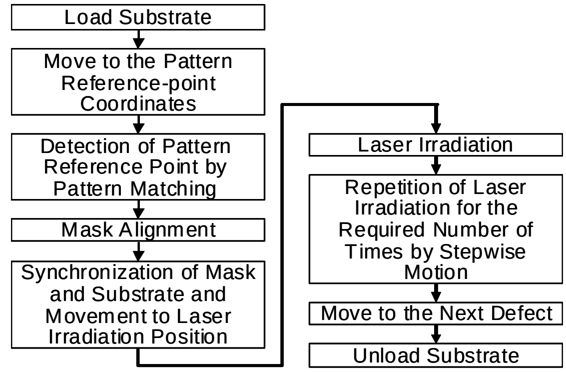


Fig.7. Flowchart for Prototype system

4. Experimental apparatus configuration

We evaluated the automatic resist pattern defect inspection and repair instrument, using a commercial visual inspection unit for the automated pattern defect inspection system. We used a prototype unit of the automated short defect repair system developed by ourselves.

Figure 6 illustrates the system configuration of the developed prototype. The prototype system is equipped with the light source of 266nm YAG laser. The optics consists of a beam homogenizer, a mask and an imaging lens. The mask is made of quartz glass with Cr pattern. The prototype is also equipped with a pattern position detection unit that positions the mask at the patterning coordinates.

The flowchart in Figure 7 shows the prototype operation procedures. The flow of operations is as follows: The substrate is loaded into the unit, and a scan is made to identify the point of reference for mask positioning near the coordinates for the defective region. After detection of the point of reference by pattern matching, the mask is placed into position. The mask and glass substrate are synchronized and moved to the position for laser irradiation. Laser irradiation is repeated while the mask and substrate are moved stepwise to correct the defect; the system then moves to the next defect. This procedure is repeated until all resist pat-tern defects have been repaired.

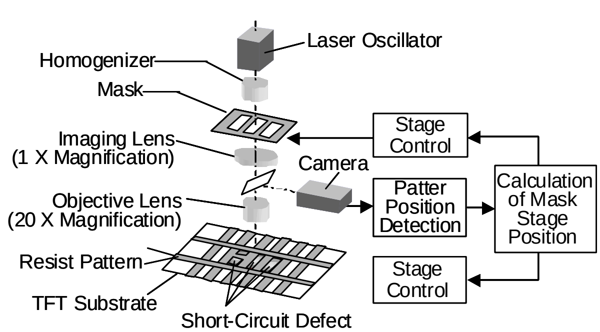


Fig.6. Configuration of the Automated Short Defect Repair System

5. Experimental Result

First, we made an evaluation of the patterning precision by using a stripe-shaped mask. Figure 8 shows the resist patterning through resist ablation mask. Figure 8 (a) shows the image of the line and space is 5/5 μm. Figure 8 (b) shows the image of the line and space is 10/20 μm. There are no patterning errors on the images. We confirmed the processing resolution is 5 μm, and processing accuracy is less than ±0.4 μm. From the standpoint of technological trends in large LCD panel, the achieved resolution will be adaptable for practical use.

Fig.9 shows the repair experimental result. Fig.9 (a) shows the resist defect image. A round shape resist defect exists in the center of the image. We prepare the resist ablation mask with regular patterns. The automated prototype system aligns it over the defect area, and then fire the laser beam through the resist ablation mask. Fig.9(b) shows the resist repair image.

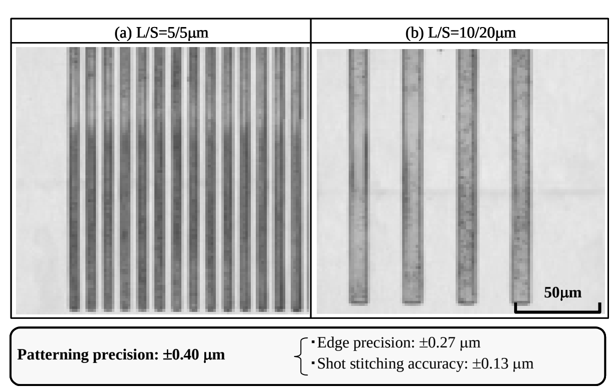
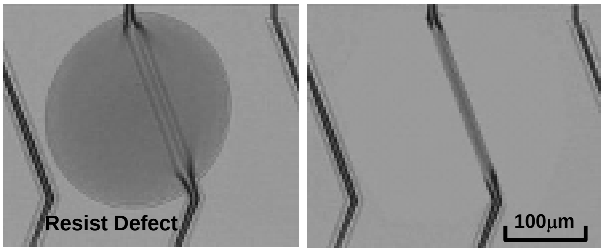


Fig.8. Resist patterning through laser ablation



(a) Resist Defect Image (b) Resist Repair Image

Fig.9. Resist defect repair experimental result

The resist pattern of the defect area is processed a regular shape.

6. Discussions

Table 1 shows the results of evaluations of the automated resist pattern short defect repair prototype unit. As Figure 8 shows, the minimum dimensions for patterning confirmed by the prototype were 5/5 µm in line and space, or finer than ±0.4 µm. The results confirmed overall mask alignment precision of tolerances smaller than ±0.5 µm, based on the images shown in Figure 8. The throughput for this run totaled 10 seconds: 4 seconds for mask positioning, 2 seconds for focusing, and 4 seconds for laser patterning.

The results (patterning resolution, precision, and time) of the experiments achieved with the developed prototype confirmed that automated resist pattern defect repairs are possible. The configuration of this automated resist pattern defect inspection and repair prototype can be applied to any system, whatever the size of the mother glass substrate. The proposed system is practical in that it can be connected directly inline to actual photolithographic processes for automatic inspections and repairs of circuit defects.

TABLE 1. Results of Prototype Evaluation

No.	Items	Design Specification	Evaluation Results
1	Minimum Patterning Demensions	5 µm	L/S = 5/5 µm
2	Patterning precision	±0.5 µm	±0.40 µm Edge Precision ±0.27 µm Stitching Accuracy ±0.13 mm
3	Mask Alingment Precision	±0.5 µm	±0.5 µm
4	Thoroughput	10 s/point	10 s/point Patterning: 4 s Focusing: 2 s Positioning: 4 s

7. Conculusions

We have developed an automated circuit defect inspection and repair method, that is adaptable for any circuit material. We anticipate that directly connecting the method developed to photolithographic process lines will realize automatic inspections and repairs of circuit defects. This method can be used for the high-yield and lowcost production of TFT-LCD panels.

8. References

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