Oil defect detection of Electrowetting Display

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ABSTRACT

In recent years, transparent display is an emerging topic in display technologies. Apply in many fields just like mobile device, shopping or advertising window, and etc. Electrowetting Display (EWD) is one kind of potential transparent display technology advantages of high transmittance, fast response time, high contrast and rich color with pigment based oil system. In mass production process of Electrowetting Display, oil defects should be found by Automated Optical Inspection (AOI) detection system. It is useful in determination of panel defects for quality control. According to the research of our group, we proposed a mechanism of AOI detection system detecting the different kinds of oil defects. This mechanism can detect different kinds of oil defect caused by oil overflow or material deteriorated after oil coating or driving. We had experiment our mechanism with a 6-inch Electrowetting Display panel from ITRI, using an Epson V750 scanner with 1200 dpi resolution. Two AOI algorithms were developed, which were high speed method and high precision method. In high precision method, oil jumping or non-recovered can be detected successfully. This mechanism of AOI detection system can be used to evaluate the oil uniformity in EWD panel process. In the future, our AOI detection system can be used in quality control of panel manufacturing for mass production.

Keywords: AOI, Automated Optical Inspection, defects, detection, EWD, Electrowetting.

1. INTRODUCTION

Electrowetting Display (EWD) was published on Nature in 2003, relative researches has been develop over the past decade [1]. Advantages of EWD are fast response, rich color selectivity, high back light usage, low power consumption and self-emittance [2-4]. Depending on the existence of reflector, EWD is distinguished into reflective, transmissive and self-emittance type [5]. Reflective EWD is considered the next generation of electronic paper technology [6], EWD retained faster response and colorful paper-like performance than conventional electronic paper technologies because of the rough reflective layer, dyed and low viscosity nonpolar liquid system [7-8]. Penetrating electro-wetting display without reflective layer has higher transmittance than conventional LCD, which means the backlight can be more effectively utilized to achieve low power consumption. It can achieved high contrast of light valve applications when used high optical density nonpolar liquid also [9-10]. Heikenfeld achieve self-luminous EWD by added a fluorescent material in nonpolar liquid and arrange an excitant backlight with light-shielding layer. It was a powerful competitive capability compare with conventional electronic paper like E-ink [11].

Electrowetting phenomenon refers to the affinity behavior of polar liquid on hydrophobic dielectric layer when applied the voltage difference between polar liquid and electrode under hydrophobic dielectric layer. The low contact angle of polar liquid represents the good affinity to hydrophobic surface. The flow direction and movement style of polar liquid can be easily controlled by patterned electrode under hydrophobic dielectric layer. The polar liquid can move in several millimeters among few milliseconds. It is widely used in microfluidic control, microfluidic lens, drug synthesis, testing and other biomedical research areas [12-14]. The principle of EWD takes advantage of electro-wetting phenomenon, the polar liquid, nonpolar liquid and hydrophobic dielectric layer are sealed within the pixel structure. A three-phase interface system lead to a balance mode in each pixel. When applied voltage between pixel electrode which under hydrophobic dielectric layer and polar liquid. The nonpolar liquid will be pushed by polar liquid because of affinity to the hydrophobic surface of the polar liquid [15-16]. The typical EWD structure is shown in Fig 1, when a nonpolar liquid having a color within a pixel, the relationship of three-phase competing can produce gray-scale display or a light-shielding effect. The response time of EWD were several milliseconds to dozens of milliseconds according to the pixels size. The driving voltage of EWD was about several volts to 25 volts and the gray scale can be modulated by different voltages of PWM signal [17-20].

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Optical Manufacturing and Testing XI, edited by Oliver W. Fähnle, Ray Williamson, Dae Wook Kim, Proc. of SPIE Vol. 9575, 957514 · © 2015 SPIE · CCC code: 0277-786X/15/$18 · doi: 10.1117/12.2187830

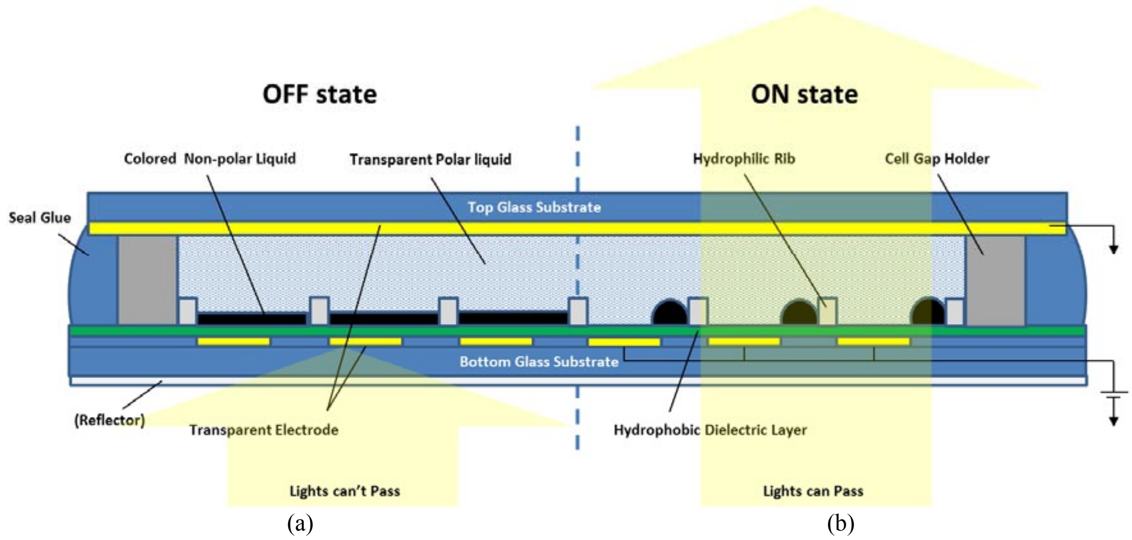

Figure 1(a). Typical EWD structure of OFF state EWD; (b) Typical EWD structure of ON state EWD

The typical process structures of EWD are shown in Fig 2(a)-(f). Fig 2. (a) shows the Patternized Transparent; Fig 2. (b) shows the High Reliable dielectric layer + Cytop process; Fig 2. (c) shows the Temporarily O2 Plasma Treatment + Hydrophilic Photo Resist process; Fig 2. (d) shows the Dip coating of colored non-polar liquid with dip coater process; Fig 2. (e) shows the Cell Assembly in polar liquid tank; Fig 2. (f) shows the Seal block glue.

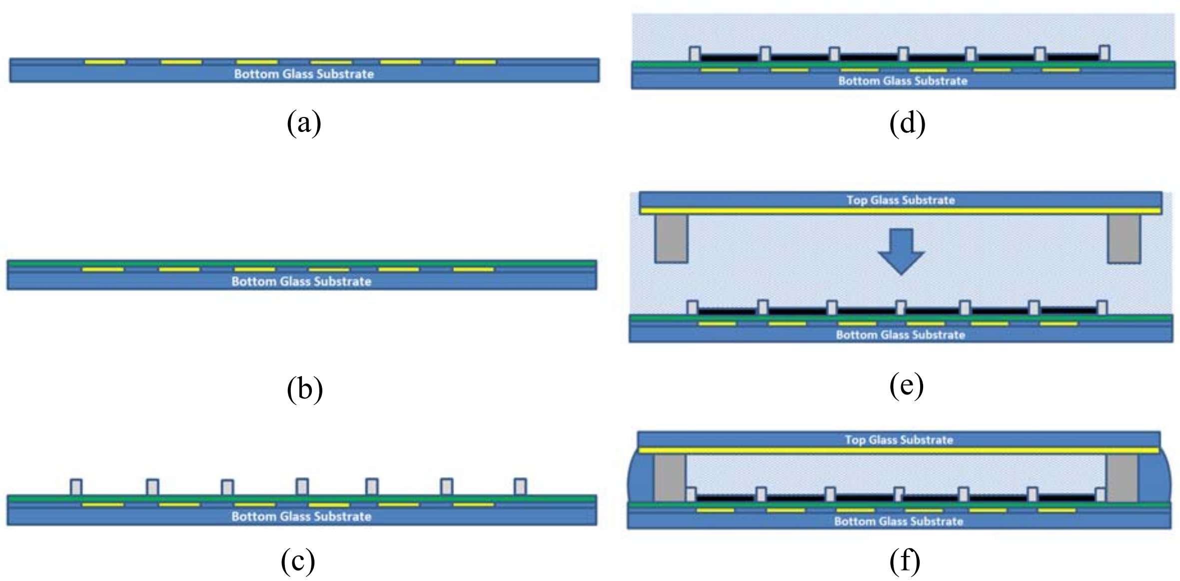

Figure 2. Typical EWD process structure. (a) Patternized Transparent; (b) High Reliable dielectric layer + Cytop; (c) Temporarily O2 Plasma Treatment + Hydrophilic Photo Resist; (d) Dip coating of colored non-polar liquid with dip coater; (e) Cell Assembly in polar liquid tank; (f) Seal block glue.

Advanced researches of EWD on international were published in recent years, Liquavista which spin off from Philips focused on the development of high-reliability electronic book [21], Industrial Technology Research Institute (ITRI) of Taiwan focused on high contrast and large area transmissive wisdom window applications [22], research team of professor Jason Heikenfeld in university of Cincinnati dedicated to the development of new EWD structure, including self-luminous, high aperture ratio, bistable EWD et al. [23-24], ADT in Germany developed bistable EWD structure and applied to ultra-low-energy display demand [25-26]. Regardless of e-books or wisdom window applications, high reliability materials, production and high yield technology development, are the key points of whether EWD access to the market quickly and successfully. In progress of production development, tools of failure classify and statistics can effectively find reasons of failure and shorten production time.

Inquiry failure type of EWD can be divided into the condition of before driving and after driving. The failures before driving are defects of non-polar liquid coating process such as error inkjet, coating lost or defects of hydrophobic layer [27]. Such kinds of defects usually cause light leakage because of none recover nonpolar liquid. The failure after driving often occurs after repeat driving of pixel. The damage of hydrophobic layer such as characteristics failure of hydrophobic ability, dielectric layer collapse, ion accumulation, etc. The nonpolar liquid will shrink when hydrophobic surface failure or ion accumulation of dielectric layer. The collapse of dielectric layer can lead to the bubble generated by polar liquid electrolyte [28-31]. Above defects are presented by shrinking of nonpolar liquid and easily observe under microscope. The degree of light leakage can be observed to judge the types of defects. But the statistics of defect numbers will waste large time by artificial calculate in high resolution panel. A fast and effective Automated Optical Inspection (AOI) system belong to EWD should be developed in necessary. Such AOI system can detect and classify pixel defects of EWD automatically. It can decrease the time of the mass production process [32].

In this paper, an Automated Optical Inspection (AOI) system of Electrowetting Display (EWD) was developed in this research for pixel defects detection and classification. A 6-inch SVGA EWD panel of ITRI was used to test this system, detected and calculated types of pixel defects successfully.

2. OIL DEFECT DETECTION SYSTEM OF ELECTROWETTING DISPLAY

According to the characteristics of defects of EWD, each pixel of a panel detecting by the AOI detection system is distinguished in three conditions: Normal, non-recovered defect, and oil jumping defect. Fig. 3 (a) shows the normal condition of EWD, Fig. 3 (b) shows the conditions of non-recovered defect, and Fig. 3 (c) shows the oil jumping defect.

(a) (b) (c)

Figure 3. (a) The normal condition of EWD; (b) The non-recovered defects of EWD; (c) The oil jumping defect of EWD.

For checking the defects of our group had developed two AOI algorithms, which were high speed method and high precision method. The high speed method is use for finding oil defects of the EWD panel, but cannot detect oil jumping or non-recovered of defect. And the high precision method, can detect either oil jumping or non-recovered of defects successfully. For the AOI algorithm process, first we scanned the sample EWD panel from the scanner. Then we selected the sample area of the panel where we needed, and decided the size of the detection mask. The detection mask go around the sample area by Z-shaped rotated. For the high precision method, we had to select the threshold value of grey-level for the detection mask. Thus the AOI algorithm could distinguished the conditions of non-recovered defect, and oil jumping defect. We also eliminated the noise of the sample image caused by manufacturing process defects or the scanning process defects. The block diagram of high speed method is shown in Fig. 4(a), and the block diagram of precision method is shown in Fig. 4 (b).

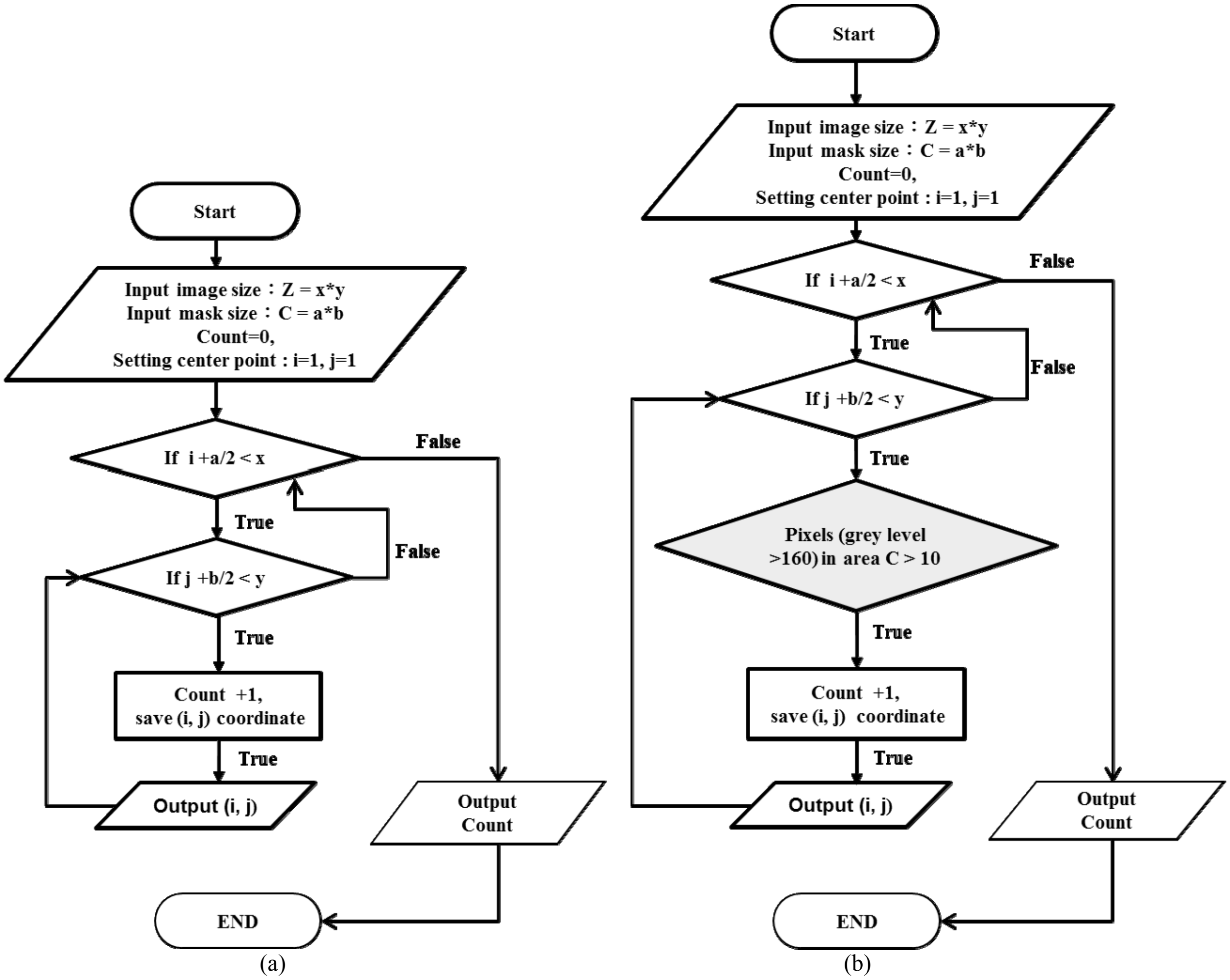

Figure 4. (a) The block diagram of high speed method; (b) the block diagram of precision method.

3. EXPERIMENTS AND RESULTS

Our group chose a scanner with 1200 dpi resolution for scanning the sample EWD panel. Since the resolution of scanner is about 2 μ m*2 μ m and the pixel of EWD panel is about 300 μ m*300 μ m, it is enough for our research. We had simulated by establishing different patterns of different conditions of oil defects. For checking the accuracy of the AOI algorithm. The patterns of point-shaped, cross-shaped, and rectangle-shaped are designed. The different designed patterns of the oil defects are shown in Fig. 5. All the designed patterns are found exactly. The high speed method is use for finding oil defects of the EWD panel, can't distinguished the defects of oil defect. And the high precision method, can distinguished oil jumping or non-recovered of defect successfully. The detection of a sample EWD panel by the high speed method and the high precision method is shown in Fig. 6.

The difference of running time using the high speed method and the high precision method was about 2 minutes and 50 minutes, respectively. The defects of a sample EWD panel detected by the high speed method and the high precision method were 1455 and 1239, respectively. Both the accuracy of the two method were over 95%. Table 1 shows the information of detecting oil defects using the high speed method and the high precision method, respectively.

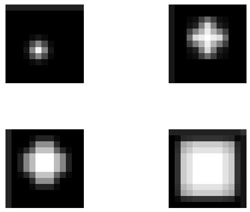

Figure 5. The different designed patterns of the oil defects.

Figure 6. The detection of a sample EWD panel by the high speed method and the high precision method.

Table 1. The comparison of the high speed method and high precision method

Items	High Speed Method	High Precision Method
Number of defect points	1455	1239
Number of Non-recovered defects	NA	643
Number of Oil jumping defect	NA	596
Percentage of defects	1.01%	0.98%
Using time	2 min.	50 min.

CONCLUSIONS

In this paper, we proposed an Automated Optical Inspection (AOI) detection system for Electrowetting Display (EWD) detecting the different kinds of oil defects for pixel defects detection and classification, and successfully detected and calculated types of pixel defects. Checking the defects by our eyes using microscope, it might cause missing and time-consuming. The AOI system for EWD provides a fast and reliable detection system. In the future, the Automated Optical Inspection detection system for Electrowetting Display process can be used for mass production of Panel manufacturing and other Semiconductor fabrications.

ACKNOWLEDGMENTS

This paper was particularly supported by the Aim for the Top University Program of the National Chiao Tung University, Industrial Technology Research Institute of Taiwan, Biomedical Electronics Translational Research Center of National Chiao-Tung University, Ministry of Education of Taiwan (Contract No. HCH102-39), China Medical University, and the National Science Council of Taiwan (Contract No. MOST 103-2221-E-009 -190).

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