Periodic Comparison Method for Defects Inspection of TFT-LCD Panel

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Abstract: - In this paper, we propose a novel defects inspection algorithm for TFT-LCD panels. We first compensate the distorted image caused by poor illumination circumstances, and compare it with the reference pattern to inspect the arrangement of the pattern on the panel. Based on the reference frame, an error value image map that shows the distribution of defects is finally obtained. The simulation example shows that our algorithm not only inspects the LCD defects well, but also is robust to the 1-pixel error.

Key-Words: - comparison, defect, etching transistor, inspection, pattern, PCRF, TFT-LCD

1 Introduction

Recently, the Liquid-Crystal Displays (LCD) device using Thin-Film Transistors (TFTs) is to find a large market as display devices for personal computers and TV. It is now important to reduce the fabrication cost and improve the quality of goods. Thus, automatic defect inspection systems become more important in industrial production lines.

These defect inspections are used not only in TFTs but also in other fields like web material, which can be divided into two classes. One is uniform, which is a region defect that differs from the background. Therefore, simple algorithms are developed such as threshold method, tracking, and delta tracker to be used to detect the defects [7, 8]. Another is textured with methods such as subtraction [8], template matching, Fourier transform, 1D AR (One-Dimensional Auto Regression) [7, 9], fuzzy logic [10], neural network [11], and Cellular Neural Network [12]-[15], etc.

With these methods, many papers have proposed to detect the defects of color filter in the TFT-LCD panel [1, 2]. They used the image subtraction. (fuzzy neural network approach [3, 4], defect detection method based on saliency map model [5], etc)

The advance of TFT-LCD panel technology causes a constraint with optical limitation to defect an inspection image system. The pattern size of TFTs is becoming smaller and the inspection image areas are becoming larger than before.. Therefore, the system is required to have both high precision and high speed [17].

Due to this situation, several methods have been studied, but they need precise image alignment without 1-pixel error [18]-[20]. However, when TFT-LCD panel image is inspected, it cannot avoid slightly distorted or rotated misalignment. Many researches have overcome this impractical problem by using an advanced method without high precision image [21]. But the more complex methods require the more computational cost.

In this paper, we are interested in defect inspection in the area of etching transistor part of TFT-LCD panel. But there are a few papers in this area. In [16], a pattern matching method is used for inspection of etching transistor part of TFT-LCD. We introduce a new inspection method named PCRF, which has a simple calculation method..

The outline of this paper is as follows. Section 2 describes the acquirement environment of etching. Section 3 proposes the new PCRF algorithm. Section 4 presents simulations and results. Finally, conclusions are summarized in the last section.

2 Environment of Image Acquisition

As the TFT-LCD becomes larger, a high resolution inspection system is required. But, practical issues, such as cost of production, lead us to find more efficient algorithms that work well with relatively low resolution images.

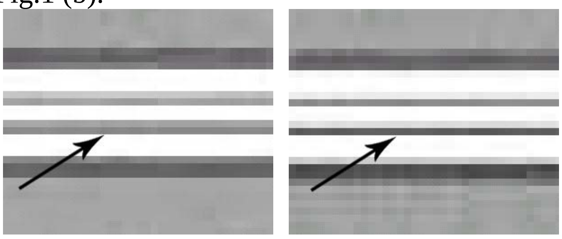
2.1 Illumination

The inspected image containing etching transistors is distorted by light source illumination. This uneven illumination causes fatal errors in the defect inspection method. The center of the image is brighter than the edge as shown in Fig.7. Fig.7 is taken from an inspection system of TFT-LCD production line.

2.2 Characteristics of TFT-LCD Panel Image

A TFT-LCD panel has numerous cells that consist of etching transistor. We could obtain similar sequential images because environment of acquisition is hardly changed. Since, each cell on the image is almost identical, we could know the size and the shape of cells..

The inspected image (Fig.7) has many 1-pixel errors, caused by low resolution. Owing to the environment of acquisition, the corresponding line of two transistor cells is not exactly identical as shown in Fig..1. A line in Fig.1 (a) has 2-pixel in widths, but not in Fig.1 (b).



(a) 2-pixel line (b) 1-pixel line

Fig.1 ±1 Pixel Error

3 Proposed Algorithm

In 3.1, we compensate the distorted image that is introduced in Section 2.1. Then, we compare the compensated image with the reference pattern to inspect the arrangement of the patterns that are located periodically by the characteristics of TFT-LCD panel. Finally, we find the defects by comparison method in Section 3.3.

3.1 Compensation of Illumination

The poor illumination makes the inspected image useless in raw as shown in Fig.7. To solve the problem, we first obtain the gray level of 1-pixel line from the inspected image (Fig.9 (a)). The higher the value, the brighter the image. Here, the red line is a polynomial curve generated in the least mean squares sense. We calculate the average of the curve and utilize it as a reference axis to reverse the curve. Then, we can obtain compensated image Fig.9 (b) by adding the result to the original image.

3.2 Pattern Search

To decrease the searching time, we shall resize the inspected image by half though sampling method. Next, we obtain the start point by using reference pattern image in restricted searching area with preliminary image information such as repetition period, total image size and cell size. Then we can obtain the precise location of repeated pattern image using template matching (shaded region in Fig.2 (b)).. Since we know the repetition period a priori, we only need to search small expected regions instead of the whole image area (shaded region in Fig.2 (c)). Finally, we can obtain the starting points of the pattern in the whole region (circles in Fig.3).

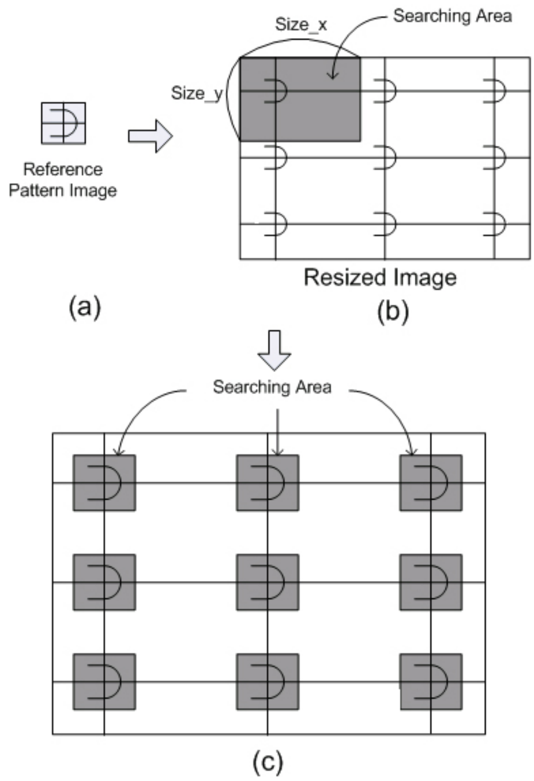


Fig.2 Pattern Searching Method

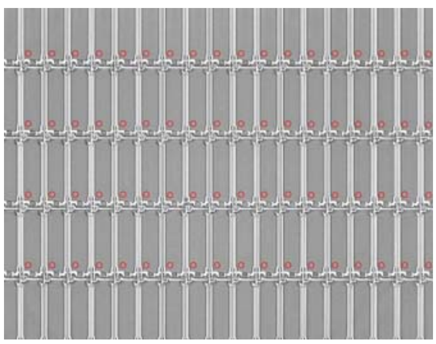


Fig.3 Starting Point of The Pattern

3.3 Generation of Reference Frame

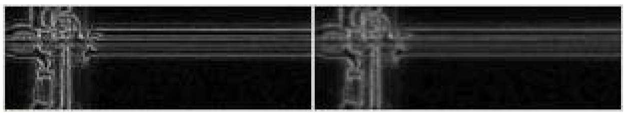
When each pattern is compared, low resolution image causes many problems. For example, the 1-pixel error value can be bigger than the real defect value. To avoid this problem, we need a kind of region-dependant threshold values. Now, we shall design a method that generates them instantly for given images.

First, we should collect some clean patterns which do not include any defect. Next, we calculate the difference of each collected image. The reference frame is calculated by the following equation.

$$I_{th}(x,y) = \max_{i,j=1,2,\ldots,n} (I_i(x,y) - I_j(x,y)), \qquad (1)$$

where I_{th} is the reference frame for comparison, and I_k is k-th clean image.. There are n clean images. Unfortunately, they have 1-pixel errors by nature and we have to modify them.

Prior to the comparison, we shall blur the reference frame to make the image robust to the 1-pixel errors.. There are many blurring methods available in the literature and we have used the Gaussian filter in MATLAB.



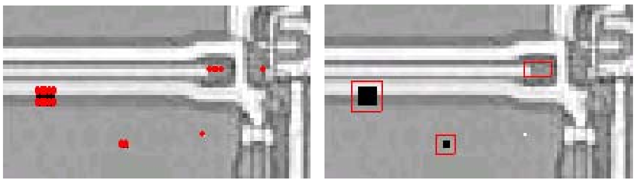
(a) Before blurring (b) After blurring

Fig.4 Reference Frame

After generating the blurred reference frame I_{th}, each repeated cell of the inspected image, $T_{i,}$ is compared to one of the clean image, I, and the error value image map, E-map, is calculated by the following operation. Here, p indicates an appropriate constant value that is dependant upon the target images.

If abs $(I(x, y) - T_i(x, y)) > p*I_{th}(x, y)$
  Then, E-$map_i(x, y)$ = true
Else
  Then, E-$map_i(x, y)$ = false
End

We remark that the 1-pixel errors in Fig.5 (a) should be discarded since they may come from the environment of acquisition, i.e. mechanical or optical errors. Finally, we obtain the defects as shown in Fig.5 (b).

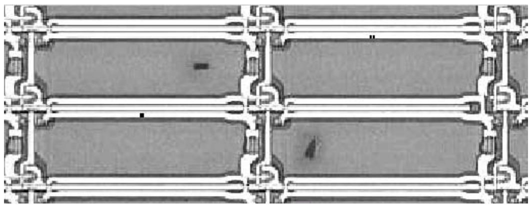


(a) Error pixel (b) 1-pixel error Eliminated

Fig.5 Indicate Defect of Image

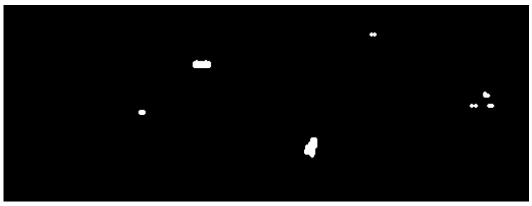
4 Simulation

We compare the simple comparison method, which subtracts the clean image from the original image, with the proposed method. Since the simple comparison method is too sensitive to the 1-pixel errors, it overestimates them as LCD defects and even does not find the real defects correctly. However, our method finds all the defects and filters out the 1-pixel errors clearly.



(a) Original image

(b) Inspected result by the simple comparison



(c) Inspected result by the proposed comparison

Fig.6 Results of Inspection

5 Conclusion

In this paper, we proposed a novel defects inspection algorithm for TFT-LCD panels. We first compensated the distorted image caused by poor illumination circumstances, and compared it with the reference pattern to inspect the arrangement of the pattern on the panel. Based on the reference frame, an error value image map that shows the distribution of defects was finally obtained. The simulation example showed that our algorithm not only inspects the LCD defects well, but also is robust to the 1-pixel error..

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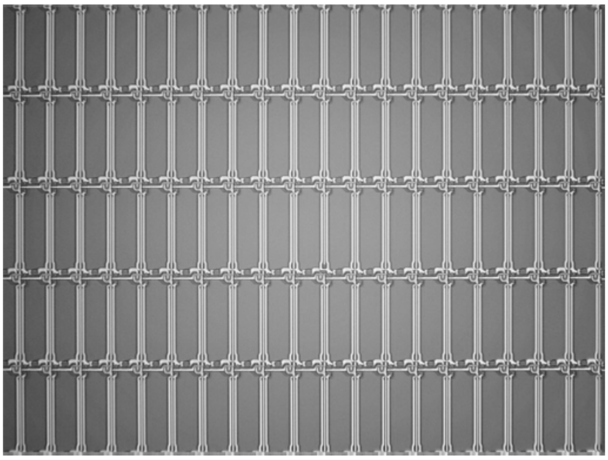


Fig.7 Inspected Image

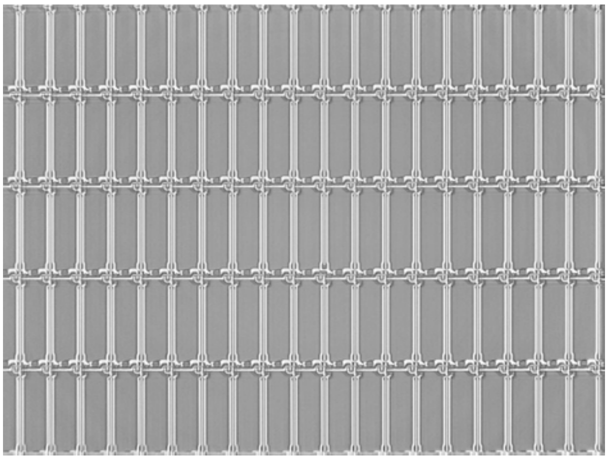
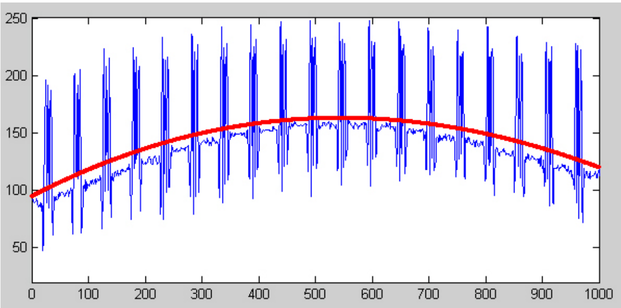
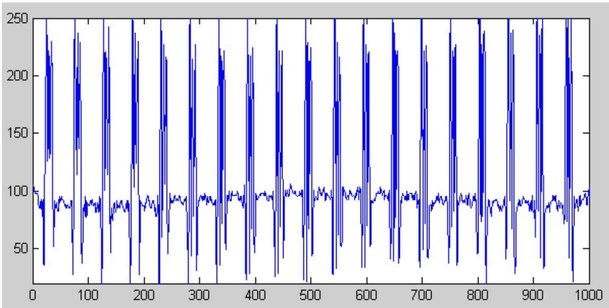


Fig.8 Compensated Image



(a) Pixel value of inspected image



(b) Compensated pixel value

Fig.9 Analysis of Inspected Image