A Study on an Inspection System of Repeated Pattern in PDP panel

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Abstract: The popularity of flat-panel display(FPD), including plasma display panel(PDP) and liquid-crystal display(LCD), has given rise to the need to streamline their production. In these days, PDP is one of the most popular display devices because of its expansion of manufacturing process and simplicity. Bus electrodes, sustain electrodes, barrier ribs and RGB phosphors are patterned on PDP panel to display an image. Since a minute damage on the pattern can cause a serious defect to display, it is important to inspect the pattern precisely. In this paper, an automatic inspection system of repeated pattern in PDP panel has been introduced to find the defect, such as open, short, dirt, island, and so on. And the inspection system has been operated in the mass production line of PDP.

Keywords: PDP(Plasma Display Panel), Inspection, Image Processing, Phosphor, Repeated Pattern

1. INTRODUCTION

As Flat panel display market is rapidly growing, major PDP makers are making large investments for new plants. To reduce the cost of manufacturing, improvement of yield is very important. With proper processing and inspection system, PDP market can improve their productivity. Automated pattern inspection system is inevitable for the manufacturing process to insure high quality and first time yield. In this paper, an inspection system, which detects defect in the layer of the PDP front panel and rear panel in mass production line, is presented

There have been many other ways for the inspection of PDP front and rear panel, it would be a convenient way to use non-contact imaging technique. Additionally, although there have been many types of imaging devices, linear CCD(Charge Coupled Device) has given us a good chance to realize a fast imaging. The linear CCD can continuously obtain the image and digitize a wider area more precisely. In particular, it could be a method to use a good image of object as a master pattern for the inspection.

These systems presented in this paper are operating in mass production line. For high-speed inspection, multiple cameras and DSP based parallel image processing systems are of general application.

2. INTRODUCTION TO PDP STRUCTURE

PDP display panel is composed of rear panel, front panel and driving circuit. Each panel has bus electrode and data electrode on glass substrate. The structure of ac PDP is shown in Fig.1. Because the pixel size of PDP is relatively large compared to LCD display, several cost effective methods are used in the PDP manufacturing process. Electrodes are commonly constructed using Photo-etching method while barrier ribs are shaped with sand- blasting and etching.

After the construct is formed on each panel, the front and rear panels are assembled and the air in-between is replaced by proper gas mixture for plasma discharge. When driving-circuit is attached to the panel assembly, the resulting part is called the PDP module. It is equipped with video processing board receiving common video signals and converting it to suitable format for driving circuit of PDP..

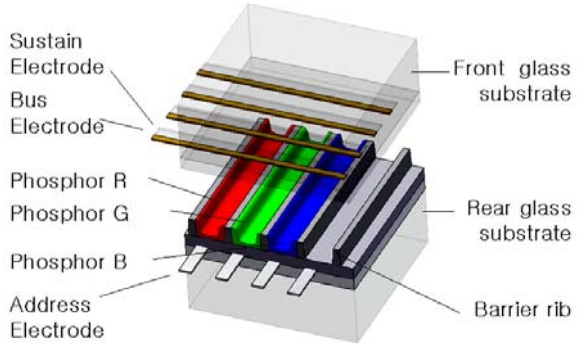


Fig. 1 Structure of AC PDP

3. PDP DEFECTS

The major PDP manufacturing stages and process steps involve fabrication, electrode pattern printing, rib pattern design, loaded board assembly, and soldered board process. Because of these complicated processes, many latent defects cause judicious damage on PDP module process.

At the module test process, several video test patterns are applied to the module. Typical video pattern includes white, red, green, blue screen and other specially designed ones. During the test, products with defective pixels are rejected.

Fig.2 shows one example of simple pixel defects found in final inspection process. The barrier rib between blue and red phosphor is not constructed properly thus plasma discharge of blue pixel at that point is observed white video pattern is red.

The cause of pixel defects shown above is open-defect of barrier rib resulting leakage of phosphor paste during the phosphor printing process. Fig.3 shows phosphor defect found in rear panel due to rib open defect of rear panel.

Because of the long lead time from each process to module inspection process, and large amount of in-process materials needed, early notification of process status is highly important.

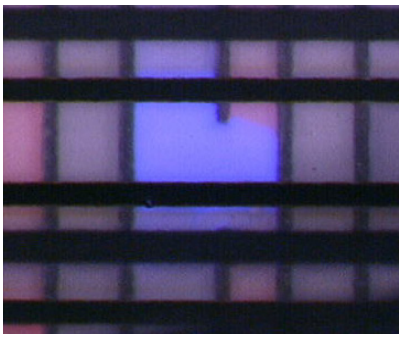


Fig. 2 Pixel defect of PDP found at the final inspection process

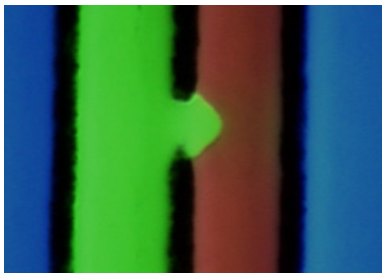


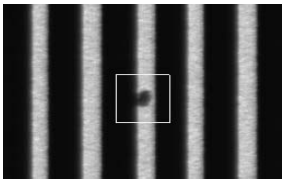
Fig. 3 Magnified view of phosphor defect found at rear panel inspection process

There are many types of defect for electrode, barrier rib, phosphor layer, ITO, dielectric layer and so on.

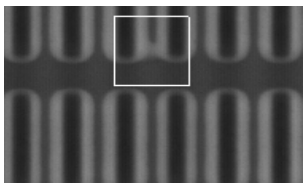
In each manufacturing flow step manufacturing process, Inspection system detects a defect and remove a panel which could effect a final inspection process after module process.

Early reducing line loss is important in recent in-line manufacturing process There are illustrated in the following figures.

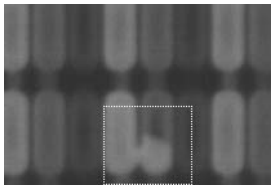
Fig.4 represent defects of rear panel manufacturing process.



(a) Bus Defect



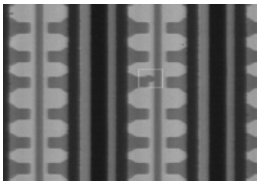
(b) Barrier Rib Defect

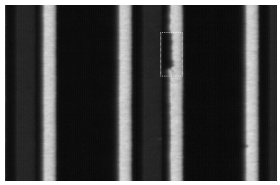


(c) Phosphor Defect

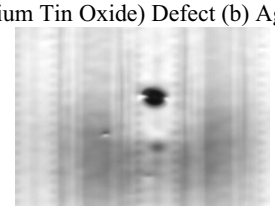
Fig.4 Defect of PDP rear Panel

Fig.5 represent defects of front panel manufacturing process.





(a) ITO(Indium Tin Oxide) Defect (b) Ag Bus Defect



(c) Dielectric layer Defect

Fig.5 Defects of front panel manufacturing process

4. PDP INSPECTION HARDWARE

4.1 Illumination and Processing System

Industrial PDP visual inspection ideally requires a cost-effective stand - alone system. This means that it should be designed to take into account operation speed, reliability, ease of use, and modular flexibility, in order to adapt to different inspection tasks. The main hardware components of the inspection system are the material and component-handling system, illumination system, image acquisition system, and the processor. The illumination system provides suitable lighting and viewing conditions to facilitate inspection, avoiding the need for additional complex image processing algorithms. The main parameters that characterize the suitability of an illumination system to acquire a quality image are: (a) intensity, (b) uniformity, (c) directionality, and (d) spectral profile. The relative importance of these parameters and the degree to which each one must be controlled are largely governed by the surface characteristics of a given PDP and the constraints imposed by the camera. For some special patterns of PDP such as phosphor, a special UV light source is needed. Images are usually acquired by use of a camera or a digitizer that acts as a sensor. There are several types of cameras available (eg. CCD, laser scanners) and the determination of the appropriate type is dictated by use. The line scan camera can be used for a high speeds inspection purposes.

The processor system usually consists of a high speeds computer. To handle multiple monochrome linear CCD at its maximum speed, the parallel processing unit, specially designed parallel image processing System, based on TMS320C64x DSP is used. It is shown in Fig.6 and designed by LG Electronics / LG Production engineering Research Center. In this system all algorithms are realized by DSP hardware, so it can process the data in real-time.

The resolution range of the PDP inspection systems employed here is 7.5 micrometer to 13 micrometer. So given a 42-inch PDP panel approximately 50GB of data must be processed in about 60 seconds.

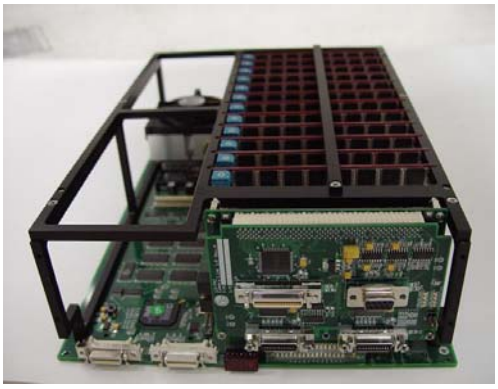


Fig. 6 Parallel Imaging Processing unit utilizing TMS320C64x DSP

4.2 Optical Consideration for Phosphor Inspection

For phosphor layer inspection UV light source is needed. When Using monochrome CCD, intensity level of phosphor layer cannot be distinguished as shown in Fig.7. So it is not adequate to detect the defect generated by going over phosphor layer in printing process.

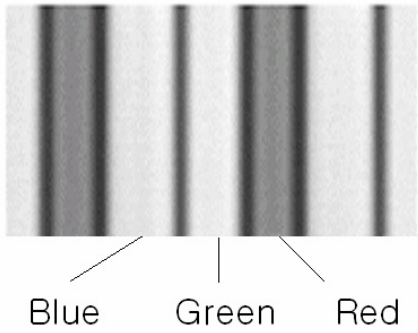


Fig. 7 Gray scale image of inspection camera

Fig.8 shows typical brightness profile of Fig.7 along horizontal direction. In the picture, intensity level of green and blue phosphor strips is almost the same.

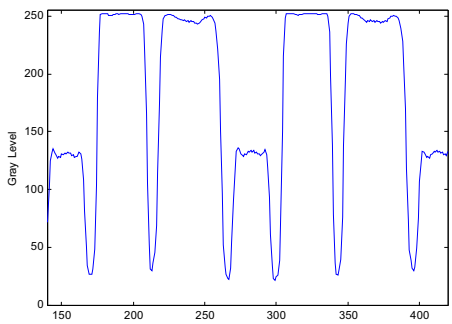


Fig. 8 Intensity Level of phosphor under 254nm UV Lamp

If dirt or scratch exists, it can be easily detected because it emits no visible light while phosphor strip beneath the dirt lit red or green or blue. The problem here is that it is not possible to detect blue drop of phosphor over green phosphor strip because of printing process. The screen-printing process of phosphor utilizes 3 masks. Typically, red, green, blue phosphors are processed in turn. After each printing process, the panel is dried in the oven and baked in the furnace.

Frequent defects are green drop on red strip, blue drop on green strip and blue drop on red strip. These combinations are consequence of sequential printing process.

In raw image shown as in Fig. 7, a drop of blue phosphor on the green phosphor strip cannot be identified because its intensity values are the same.

To get distinguished intensity level for each phosphor using monochrome CCD, special color filters are adopted in front of the imaging lens. Fig.10 shows an example of color filter design and Fig. 11 shows the modified inspection image by using the color filter.

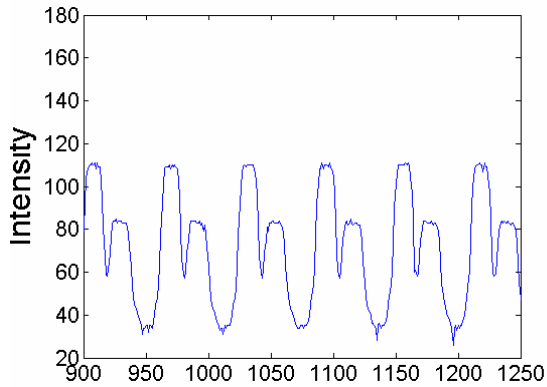


Fig. 9 intensity profiles with designed color filter

The resultant intensity profile along horizontal axis is shown in Fig 9.

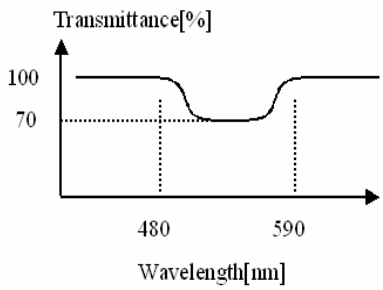


Fig. 10 Transmittance design for optimum color filter.

Green drop on red strip, blue drop on green strip can be readily distinguished and dark spot on any strip is dirt because it emits no visible light under UV light.

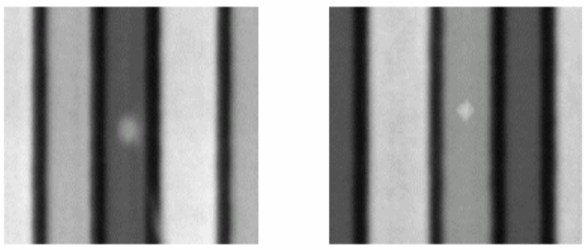


Fig. 11 Defect image with color filter

The defect can be easily identified by its brightness intensity of itself and its surroundings. As a results, defect is achieved readily achieved with simple algorithm

5. INSPECTION ALGORITHM

5.1 Pitch-wise Comparison

Several inspection methods are being used in the pattern inspection systems operating at various application site of display industry. The method adopted in the system stated in this paper is rather well known 'Pitch-wise comparison' method.

Pitch-wise comparison is a very popular algorithm used for inspection of products that are made up of a series of repeating patterns. Pitch-wise comparison is used to verify the pattern integrity on PDP front and rear panel after the patterning process. Let's consider the methods of horizontal line comparison. If there is a defect, two adjacent horizontal lines are different in its intensity level, and this difference is a clue of defect. A period of repetition pattern is calculated as following equations.

A repeated pattern is represented as follows,

$$g(x+p,y)=g(x,y) \tag{1}$$

Pixel value can be represented as g(x,y) and the numbers P is called *Pitch* of g(*x,y*).

Pitch is calculated automatically by following equation within applied field of view.

$$p(\rho)=\sum_{x=fovStartX}^{fovEndX}|\,g(x,y)-g(x+\rho,y)\,| \tag{2}$$

Pitch of repeated pattern is determined by minimum value of from finding pitch start value to end valued.

$$p=\min\left|p(\rho)\right|_{sx}^{ex} \tag{3}$$

Each Panel has repeating and identical patterned positions. Therefore by comparing adjacent patterned positions (position A to position B) you can determine if one or both candidate have potentially defect areas. By comparing a third position (position C) one can determine which candidate if any in positions A and B was defective. As shown in Fig.12, the defects can be detected by comparing part A with part B, and part B with part C, and part C with part A, the difference will be defects. It can be realized by image delay with the help of image processing hardware.

Egs(4) means numerical deference of comparing adjacent pattern position.

$$\begin{aligned} D_{left} &= \left|g(x,y)-g(x-\rho,y)\right| \\ D_{right} &= \left|g(x,y)-g(x+\rho,y)\right| \end{aligned} \tag{4}$$

$$\begin{aligned} g_{white}(x,y) &= \begin{cases} 1 & if((D_{left}>\tau_w)\otimes(D_{right}>\tau_w)) \\ 0 & \end{cases} \\ g_{black}(x,y) &= \begin{cases} 1 & if((D_{left}<\tau_b)\otimes(D_{right}<\tau_b)) \\ 0 & \end{cases} \end{aligned} \tag{5}$$

Defect candidate are generated by established thresholds and a simple logic has been employed as shown in Eqs(5).

Where $g_{white}(x,y)$ and $g_{black}(x,y)$ represent white and black pixel candidate respectively.

After simple detection, lots of small detect candidate are generated. After several small defects are scattered resulting multiple review points.

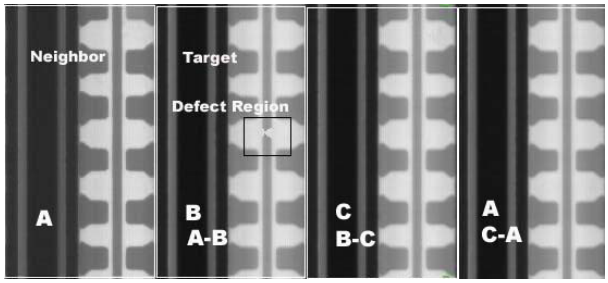


Fig. 12 Gray scale image of the defective area on the PDP Front Panel

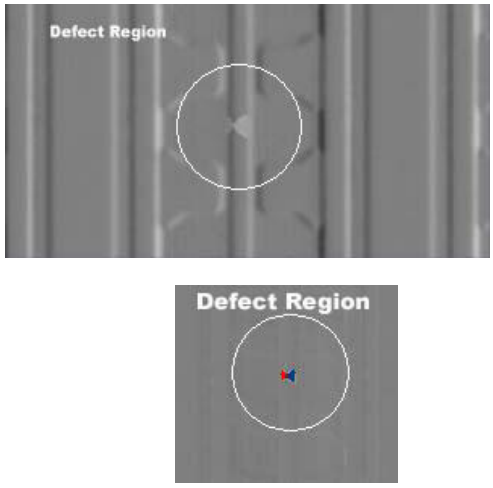


Fig. 13 Result of detecting

A Pitch-wise comparison result of classical and proposed method was shown in Fig.12~Fig.13.

5.2 Blobs and Defect Classification

After image difference, the binary image can be blob analyzed using many different algorithms. If some small blobs on the view image are found, they can be considered as dust or anomalous. So far, some methods for object recognition based on global feature measurements such as object's area, size as well as shape measurement techniques have been considered.

To detect defects with the help of boundary descriptors is possible. Here the linear regression and local description length method is used for detecting the bite and protrusion defects. Another useful idea is that some small acceptable defects could be also detected with the computation of the maximum residual based on linear equation regression for the electric trace of PDP. A mathematical model of the linear regression can be described as follows.

Given the local boundary coordinates such as $(x_1,y_1),(x_2,y_2),l,(x_n,y_n)$ then we have the equation

$$y_t=ax_t+b+e_t(t=1,2,..,l,..n) \tag{6}$$

Ordinary least squares estimators of a and b are given by

$$a=\frac{\sum(x_t-\bar{x})(y_t-\bar{y})}{\sum(x_t-\bar{x})^2} \tag{7}$$

$$b=\bar{y}-a\bar{x} \tag{8}$$

Based on the above equation, the local maximum residual can be computed according to the value of the local residuals,

the defects can be judged as acceptable or not acceptable. If the residual is bigger than a given threshold, the defect is deemed not acceptable, otherwise the defect is accepted. Also, the defect type can be classified by whether or not it is a white or black defect. So the comprehensive algorithms are used for different kind defect classification.

A inspection and image processing process can be described using the flowchart in Fig.14 .

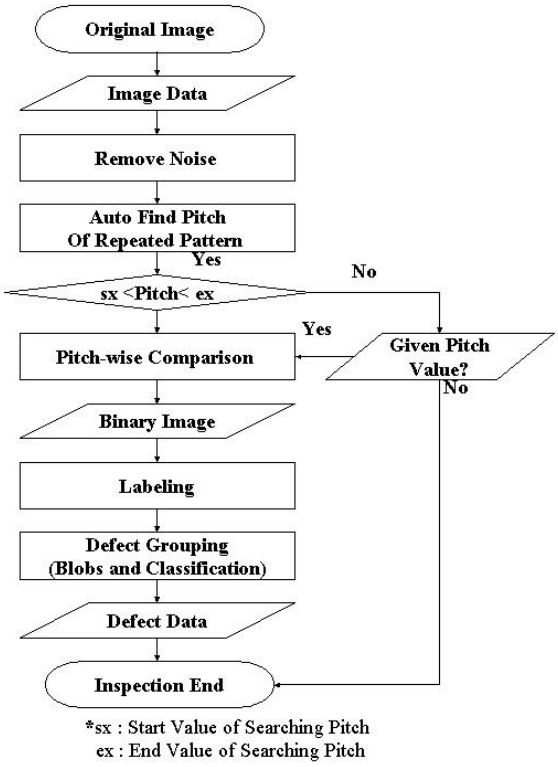


Fig. 14 Flowchart of inspection algorithm

5. INSPECTION SYSTEMS AND APPLICATION

A system has been developed for the inspection of PDP front panel and rear panel. Fig. 15 shows the layout of PDP in-line pattern inspection system and Fig.16 shows the special UV illumination system of phosphor inspection. A high-speed linear CCD has been employed to image the pattern and a high-precision moving stage has been used for glass moving.

Although the target glass size, multi-panel on a glass, is as big as 2000 x 1200 [mm^2], it should be inspected within 90 seconds.

These systems have been installed in the factory of LG Electronics in Korea since January 2004. The system composed of three kinds of modules as lightening module, lens and linear CCD module and review camera module. After inspect the glass, defect is reviewed and repaired using high-resolution review camera and laser repairing module.

When the system was operated in high-resolution mode, it can detect small defect coming up to 0.015[mm] beyond 98% reliability. Rate of false defect are small as 2%. Several types of pattern can be repeated on the glass and pattern period depends on the panel size i.e. 42”, 50”, 60”, 71” etc.

Pattern shape is various per manufacturing company and its design rule is confidential.

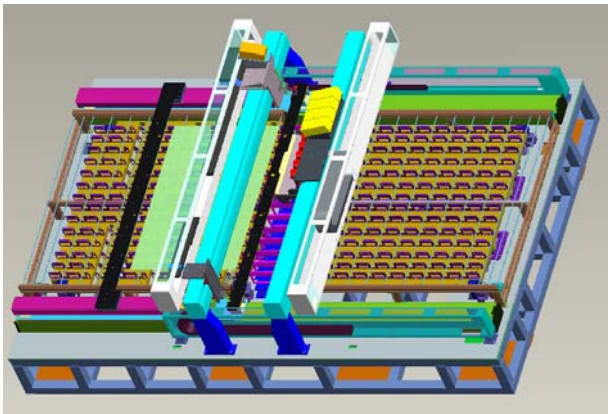


Fig 15 Drawing of developed inspection system

Although there have been many kinds of defects on the pattern, the defects can be detected by proposed inspection algorithm consistently. Since there have been many types of defects, it is not easy to classify the defect. However, the classification method is beyond the scope of this study and a future works

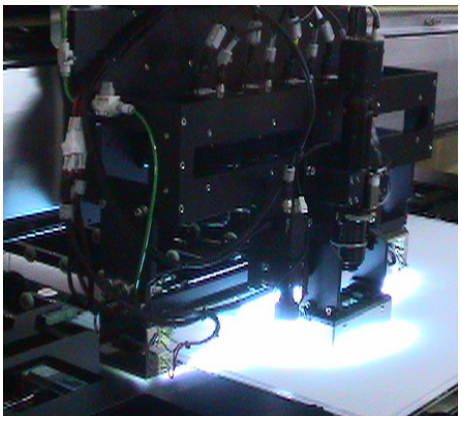


Fig. 16 UV Illumination of Phosphor Inspection System

6.CONCLUSION

This paper introduces an inspection method and inspection system for repeated pattern of PDP front panel and rear panel.

For various pattern inspection of repeated pattern, such as phosphor layer, bus electrode, dielectric layer, and barrier rib in panel process, pitch-wise comparison method and classification has been introduced.

Also for the phosphor inspection using UV illumination optical filer has been designed to monochromic CCD.

The discussed algorithms and inspection systems works well for defect detection and classification and have been employed to the inspection system and the system was able to contribute for filtering faulty products successfully.

Defects such as cut, bite, short, protrusion, pinhole, and island are properly identified on a PDP review station. The systems are successfully being used in the PDP manufacturing line.

For high-speed inspection, multiple cameras and DSP based parallel image processing systems are general application

With the development of PDP technology, the PDP pattern will be modified in the future, so modified inspection

algorithms will be required. The existing methods are expected play an important role in the inspection of PDP.

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