Determination of geometric stability of glass substrates using machine vision

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Abstract: The stability of glass substrates is an important concern for the flat panel display industry. High-resolution displays have very tight geometrical requirements and alignment of the various display components is critical if good performance is to be obtained. Prior to development of manufacturing processes for these displays, it is necessary to determine how glass substrates change during the various processing steps. This paper describes a system to measure electrode patterns before and after critical processing steps for color plasma panels. The electrode patterns, which are made of thin-film gold, are a series of parallel electrodes. In order to measure electrode locations, a vision system consisting of an X-Y stage, a video camera, a frame grabber, and a PC-compatible computer was used. Images captured with this setup were processed to minimize the effects of noise and improve accuracy. A gray-scale interpolation technique in which the centroids of the electrodes are calculated was used to enhance measurement resolution.

1. INTRODUCTION

Flat-panel displays represent one of the key technologies of the future. AC Plasma panels, one example of flat display, consist of two glass plates or substrates separated by a small and very uniform gap as shown in Fig. 1. Each plate has an array of parallel gold electrodes with a pitch on the order of 60 lines/inch. The electrodes are covered by a clear dielectric material and the two plates are oriented so that the electrode patterns are orthogonal to each other as illustrated in Fig. 1. The plates are sealed together to form a gap between the opposing dielectric surfaces. Each intersection of two electrodes defines a display pixel or cell that can be lit or extinguished under control of the driving electronics. Spacers are provided at regular intervals to maintain a uniform gap of approximately four mils over the panel area.

Traditional plasma panel displays use a gas mixture primarily composed of neon with trace amounts of argon or xenon. Such displays are characterized by their bright orange color and are used in a variety of applications where factors such as the presence of strong magnetic fields, size, and weight limit the use of CRT displays despite their low cost. The advent of high-definition television with the requirement for large viewing areas has renewed interest in plasma panel displays due to the substantial physical space needed for CRT displays.

Since traditional plasma panels are monochromatic they are not suitable for television applications. The use of phosphors and a gas that emits large amounts of ultraviolet light is necessary to produce true-color images. Triads of red, green and blue phosphors must be deposited accurately to maintain the necessary alignment with the electrode intersections.

Maintaining this alignment, however, is quite difficult over large areas because the glass substrates tend to shrink during various high-temperature manufacturing processes, such as dielectric firing and sealing. An understanding of the exact manner in which substrates change during these processes is required in order to design phosphor deposition artwork that will be properly aligned with the electrode patterns. Dimensional changes in the glass substrate are less than the distance between electrodes, so measuring electrode positions before and after each processing step provide an accurate measure of substrate stability.
A project has been initiated to evaluate how substrates changed during various processing steps. The changes are typically on the order of parts/thousand so highly accurate measurements are needed. Also, it was very desirable to use existing equipment in order to minimize cost. A system for measuring spacers and dielectric thickness was available and could be modified to make the new measurements. In the following sections, a description of the basic system will be provided along with the analysis techniques that were developed.

2. THE MEASUREMENT SYSTEM

The basic measurement system consists of an X-Y stage to move a given panel substrate for gauging and feature identification, a PC-compatible 486 computer with image acquisition hardware and an illumination source. A light section microscope with video camera and an alignment camera are also present in the system but were not used for dimensional stability measurements. A third camera was added for the new measurements.

2.1 X-Y Stage

In order to perform measurements at various locations on a given substrate, an X-Y table with stepper motors is used to position it. With this arrangement, the substrate is mounted on the table using a fixture to secure and position the substrate in a consistent manner on the table. Since some variation in the electrode pattern relative to the substrate exists, X and Y offset adjustments are made using a fiducial reference point in the electrode pattern.

The stepper motors are driven by a pair of controllers that accept ASCII commands from the host computer via a serial port. The controllers provide the necessary velocity profile by controlling acceleration and deceleration to minimize the time required for movement without sacrificing accuracy.

2.2 Image capture hardware

For image acquisition, a standard RS-170 camera is used to observe selected substrate areas. A field of view approximately 0.2 by 0.15 inches is obtained with a 75 mm camera lens and extension tube. A combination VGA and frame grasper card digitizes and stores the video signal. A live video image can be shown on the VGA monitor with this board so that an additional monitor is not required for setup. The VGA memory is also used for image capture so that text or graphics could be combined with a recently captured image. A more complete description of this approach is available in another paper in this conference.

2.3 Lighting

Since the electrodes are opaque, the best illumination technique is back illumination. However, no provision was made originally for this type of illumination since the system only used a light section microscope for measurement. A back-illumination source would be difficult to implement so an alternative technique was used that took advantage of the specular properties of the electrodes.

Because the panel electrodes have a mirror-like surface, a dark field approach was used as illustrated in Figure 2. Here, incident light parallel to the electrodes strikes them at a low angle. This light is reflected away from the camera so the electrodes appear dark. The white surface under the substrate reflects light diffusely and appears bright relative to the electrodes.

As will be noted later, this type of lighting causes a noticeable gradient across the image in which the side nearest to the light source is markedly brighter than the opposite side. As described in the next section, simple image processing can eliminate problems resulting from this nonuniformity.

![Figure 2. Light striking the electrode pattern at a low angle is reflected away from the camera and appears dark.](image-url)
3. IMAGE ANALYSIS ALGORITHMS

The basic approach to determine the degree of change between different manufacturing steps takes advantage of the regular parallel electrode pattern on a substrate. Measuring the location of each electrode relative to some reference point provides a straightforward technique to determine how a substrate changes.

3.1 Image acquisition and processing

A matrix of 0.2 by 0.15 inch measurement regions was defined for a given type of panel substrate and each was moved under the camera and captured at a resolution of 640 pixels/line by 480 lines. A typical image, given in Fig. 3, shows the panel electrodes as dark horizontal lines against a brighter background. A light gradient is evident in the image which is caused by lighting the substrate from only one side. Image processing is used to minimize any errors caused by the nonuniform illumination.

It may be noted that there is a great deal of redundancy in the image. The important information can be retained by reducing the image resolution in the horizontal direction by summing adjacent horizontal pixels. This will provide faster processing since the image size is much smaller and, more importantly, reduce image noise because of pixel summing. A reduction factor of 16 was used for this application so that the final image resolution was 40 pixels by 480 lines.

After reducing the horizontal resolution, a gray-scale logarithmic transformation is performed to minimize the effects of nonuniform illumination. A gray-scale closing operation is used to estimate the background light level which is very effective. Since the electrodes are less than 10 pixels high, a vertical structuring element of this length or greater will remove them. Subtracting the original image from the closed image provides an illumination-corrected image in which the electrodes appear as bright horizontal lines against a dark background. A plot of light level versus scan number given in Fig. 4 illustrates this.

The centroids for each electrode at a given x (pixel) locations is calculated using

\[ \mu_d = \frac{\sum g(x, y) \cdot y}{\sum g(x, y)} \]

in which \( \mu_d \) is the centroid for the kth electrode and the column of pixels at x and g(x,y) is the gray level for the pixel at (x,y). The pixels used for this calculation are those corresponding to the kth electrode that are above gray level 10. The location of each electrode was found by averaging all of the centroids for that line. An error estimate was calculated at the same time and in general was well under 0.1 mils which is greater than the accuracy of the X-Y stage.

4. RESULTS AND CONCLUSIONS

Measurements were made before and after various processing steps and analyzed using statistical
techniques. A model was constructed from these results which showed a linear correlation between distance from a reference point and the amount of compaction with a correlation of 98%. A plot of the results is given in Fig. 5.

From this model, artwork for phosphor deposition can be designed that will be properly aligned with the electrode pattern. Measuring electrode locations by calculating gray-scale centroids is an effective and accurate way to improve vision system resolution for this type of application.

REFERENCES

