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ABSTRACT

A system for measuring barriers in a color AC plasma panel has been developed. Barriers are used in this type of display to prevent phosphors in cells adjacent to lit cells from being excited which adversely affects color purity. The geometry of the barriers is a significant factor for successful operation of color plasma panels and must measured to verify that the barriers are within specifications. Barrier height is on the order of several mils with a pitch of about five mils. A system developed for spacer measurements was available for this application. However, it did not have sufficient light sensitivity because the barriers reflect light much less efficiently than traditional panels. The original system employed a light section microscope for height measurement which was reasonably well suited for barrier measurements except that a green filter was an integral part of the instrument. Because the microscope was originally intended for manual measurements, the green filter improved measurement accuracy. The green portion of the spectrum is most suited to the human visual system with respect to both sensitivity and resolution. With a CCD camera, however, this is distinctly suboptimal given the relatively weak response of the camera and the relatively weak emission of incandescent sources in this portion of the spectrum. Because the green filter is an integral part of the microscope, there was no way to remove it. For this reason, several modifications were required to a lamp with a higher color temperature which increased the amount of radiation in the green portion of the spectrum. The video amplifier gain was boosted significantly in the frame grabber and frame integration was provided to reduce noise. Finally, background subtraction was provided to remove shading variations associated with the normally insignificant dark current of the CCD sensor. Once a good image had been obtained, morphological processing was performed to reduce noise and centroid calculations were performed to provide an accurate measure of the barrier surface height.

Keywords: measurement gauging noise low-light

1. INTRODUCTION

High-definition television technology is currently under development and promises to offer much higher picture quality compared to traditional video hardware. One problem area for the new technology is the lack of suitable displays. While CRT displays can provide the needed resolution, the physical space required for large screen sizes is a significant limitation. Flat panel displays represent an alternative approach that overcomes space problems. Large monochrome plasma panels have been in production for some time and are not too difficult to manufacture.

However, color displays are needed for the television market and this increases manufacturing complexity. Additional electrodes and phosphors are needed to produce three colors. Furthermore, barriers between cells are needed in order to prevent phosphors in unenergized cells from being excited by adjacent on cells. A typical example of a color plasma panel with barriers is shown in Fig. 1.

![Figure 1. Drawing of a typical color plasma panel with barriers.](image)

This paper describes hardware and software for measuring such barriers in a new plasma panel being developed. The hardware was originally developed for measuring plasma-panel spacers but more recently has been used to measure panel dielectric thickness and geometrical stability. As will be noted later, the hardware, described in the next section, is not very suitable for barrier measurements but functions adequately for evaluating new panel designs. Special software, which is discussed in section 3, was developed to minimize hardware deficiencies at the expense of extra processing time. In the last section, results and future plans are presented.
2. DATA ACQUISITION

In order to achieve accurate measurements, various components including the LSM, video camera, frame grabber, and motion control hardware had to be assembled into a suitable system. The LSM was the most important component since it provided images that could be analyzed to extract three-dimensional information including dielectric thickness. A general overview of the system is shown in figure 3, illustrating the various system components.

2.1 Surface Profile Measurements

The LSM is a surface testing instrument which produces a surface profile. With this method, an optical "cut" is made across the surface to be measured using structured light. An incandescent lamp is masked by a slit and the result is focused using an objective lens. This produces a narrow band of light at a 45 degree angle to the surface of the dielectric surface. The light band is reflected off of the surface and is imaged by the microscope at the 45 degree angle of reflection corresponding to the angle of incidence.

Figure 2. Hardware used for dielectric thickness measurements. The box in the lower left corner provides additional information about the optical head.
A cross-line reticule is provided in the eyepiece for manual measurements but is not used in this application. A camera port is provided on the microscope suitable for use with a video camera. A moveable mirror is provided to select the camera port or eyepiece but for this application, the camera port is normally used.

### 2.2 Motion Control Hardware

In order to measure dielectric thickness at various locations on a glass substrate, either the substrate or microscope must be moved. Moving the substrate was more practical since it weighs less than the microscope and video camera assembly and has no cables attached. An X-Y table with stepper motors is used to position the substrate. With this arrangement, the substrate is mounted on the table with a fixture to secure and position the substrate in a consistent manner relative to the table. Given that there is some variation in the electrode pattern relative to the substrate, X and Y offset adjustments can be 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 cable. The controllers provide the necessary velocity profile by controlling acceleration and deceleration to minimize the time required for movement. A variety of commands may be presented to the controllers such as relative and absolute moves, setting various motion parameters, enabling either the X or Y controller, etc. Status information is obtained by reading characters from the controller after the appropriate command has been issued to it.

Since panel substrates will not be perfectly flat, it is also necessary to control the distance between the microscope and the surface in a given region of the substrate. In this case, the microscope is moved since the distance is quite small. As the X-Y stage moves to a given location, the microscope height is adjusted so that the dielectric surface remains in the same relative position in the field of view of the LSM.

After each image acquisition, the dielectric surface is identified and a corrective movement is made if the position of the surface was above or below the target location. If the discrepancy is large, a new image is acquired after correction. Generally, a second image is only required when moving to a new spacer location.

### 2.3 Image Acquisition Hardware

For image acquisition, a standard RS-170 camera is attached to the camera port of the LSM using a custom C-mount adapter. A combination VGA and frame grabber card digitizes and stores the camera 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 may be combined with a recently captured image.

## 3. IMAGE ACQUISITION AND PROCESSING

### 3.1 Image Acquisition

A camera mounted on the camera port of the light-section microscope in conjunction with a Scorpion frame grabber is used to acquire barrier images. Light levels in these images are often quite low which adversely affects detection of the surface reflection. Barriers tend to reflect light diffusely rather than specularly unlike glass or metal surfaces.

A typical barrier image is shown in Figure 3 which illustrates the problem. This image was obtained by adding 16 video frames together to suppress noise which otherwise would have masked the faint detail. The analog video gain in the frame grabber has been maximized to capture faint features with an appropriate offset, and the digitized contrast has also been increased substantially. Some shading exists in the image since the top of the image is brighter than the bottom. With brighter images this would not be apparent or significant. In comparison, the primary reflection from the dielectric surface in standard panels is typically two orders of magnitude greater.
A number of factors account for the very low contrast of important features. The etched surfaces are highly diffuse and reflect light weakly. Very little light is reflected from the side-walls into the camera so they are not, for the most part, visible. The light-section microscope uses a green filter to provide monochromatic light. Unfortunately, the CCD camera is not very sensitive to this portion of the spectrum although it is optimal for manual observations. Image processing is required to extract meaningful data from such images.

A background image, consisting only of the background shading captured prior to barrier measurements, is subtracted from the image of Figure 3 to generate the image given in Figure 4. The shading has been significantly reduced but random noise and the residual shading is still present.

**Barrier Position Estimation**

To increase the speed of processing, only the rows of the image actually surrounding the barriers are captured at high resolution. Determination of the top and bottom rows is accomplished by initially acquiring a low resolution image. The low resolution image also sums 16 frames and then subtracts the background, resulting in the image shown in Figure 4.

A centroid is calculated for each column of the image in order to determine the barrier height, width and spacing. The position of the centroids is used to separate the barriers from the valleys as shown in figure 5.

One-dimensional morphology is used to estimate the remaining shading in the column sum of pixels by means of a gray-scale opening with a linear structuring element of 50 pixels. The opened data is then subtracted from the original data so that most of the remaining pixels have a gray-scale value relatively close to zero except for those corresponding to the surface reflection. This is shown in figure 5 where the image has been summed across each row to produce a single column of data.

**System Operation**

Barrier inspection is available from the DOS command prompt through utilization of batch files. One batch file is used to acquire the background image while the second batch file controls
acquisition and processing of the barrier images. The operation of the two batch files is presented in the flow chart of Appendix A, while program and data files are listed in Appendix B.

RESULTS

Production System Issues

Based on this feasibility study, a production system for barrier inspection would utilize major improvements to the camera and optics. These improvements would enable an increased number of samples per panel while permitting faster inspection. A discussion of the limitations and proposed improvements follows.

Current Limitations

RS-170 cameras are not very suitable for barrier measurements for several reasons:

- Fixed integration time is not good for low-light conditions encountered with barriers.
- Aspect ratio of 4:3 is far from optimal if more than a few barriers are to be imaged simultaneously.
- Cameras are noisy which reduces accuracy of measurements.

Light-section microscope likewise has limitations.

- Field of view of microscope is too small with respect to horizontal coverage.
- The green filter which is an integral part of the microscope is quite sub-optimal for CCD cameras with incandescent sources. Incandescent sources provide much more energy in the red and IR portions of the spectrum and CCD cameras are much more sensitive to this type of radiation.

REFERENCES