Deformation Analysis on the Photospacers for TFT LCD

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Abstract: *The measurement system has been set up successfully for evaluating the luminance decay resulted from finger touch. Experimental result showed that in the same density design, larger photospacer will be with a better cell gap stability than that of smaller one and also with a satisfied one drop fill (ODF) margin.*

Keywords: photospacer, cell gap, ODF.

Introduction

In general, a liquid crystal display (LCD) device has a pair of substrates each having transparent electrodes and a liquid crystal sandwiched between these substrates. The space called "cell gap" between these two substrates plays an important role to affect optical characteristic of LCD device, especially the transmitting of light.

Therefore, the uniformity of cell gap through the entire panel would be very important. It is well known that any slight deviation in the cell gap will result in a noticeable and defective appearance in the display (so-called mura defect) [1]. This can readily be seen in a conventional LCD panel with a fingertip pressure on the surface. By applying a fingertip stress on the panel surface, the cell gap will be decreased for some extent due to the reduction of photospacer height. Because of the cell gap reduction, a black spot (or called touch mura) resulted from the decay of luminance can be easy observed. There are two cases for the black spot phenomena which need to be concerned. One is resulted from reversible deformation of the photospacer, another is resulted from plastic deformation of photospacer. For case one, the black spot will be recovered after the release of applied pressure, such as finger pressed loading from human and another case is that the black spot will not be disappeared after the release of applied pressure.

In order to reduce the plastic deformation of photospacer, usually a photospacer material with larger elastic module was employed to enhance the resistance to applied pressure. In contrast, there is also a side effect of bubble existed in the panel for a photospacer with a larger elastic module, which has been proposed by Lee et al. [2]. On the other hand, ODF margin (tolerance of liquid crystal injection amount in ODF process) is also an important parameter that should be taken into consideration in photospacer design. In other words, it is necessary to design a proper photospacer with a larger ODF margin and excellent resistance for touch mura.

Although much effort has been done to design a proper photospacer [3~5], seldom paper has mentioned to the test method or evaluate technology for touch mura specially for quantitative data on the luminance decay under different applied force or loading. In this paper the luminance decay for various designs of photospacers under various compressive stresses was investigated. In addition, however, most pressure applied on the panel is absorbed by bending of substrates and support members of backlight. Before the un-recovered touch mura appears, the panel might be destroyed by bending when the pressure is about 4 kgw/cm^2. For this reason, a new test method was proposed to estimate the ability of photospacer to resist touch mura. Since luminance is mainly related to cell gap and photospacer height, this new method was used to estimate damage of photospacer by luminance change measurement.

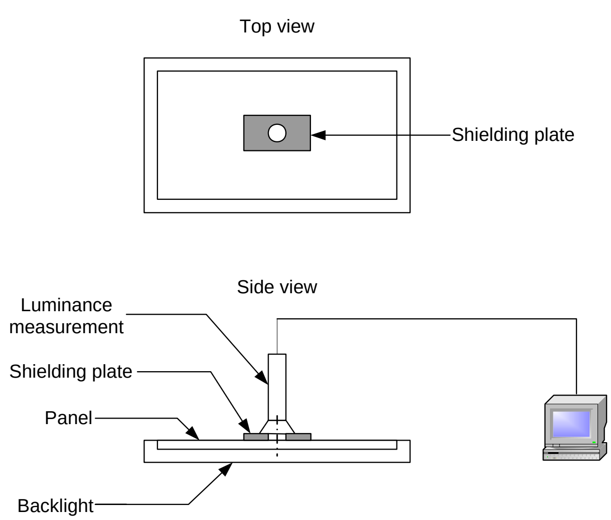

Figure 1. Schematic illustration of measurement method.

Experimental Procedure

A schematic illustration of the built-in device for evaluate the luminance change under various pressure are shown in Fig 1. As can be seen in the Fig. 1, the CA-210 was used to measure the luminance change before and after the loading test. The photograph for the actual test condition is shown in Fig. 2. As can be seen in Fig. 2, a serious of specific counterweights were used to form a desired test pressure onto the surface of panel. The photograph of the counterweights is shown in Fig. 3. It can be seen in Fig. 3 that there is a tip part marked by the red circle and to simulate the finger touch force by using this part. For 30 minutes after the loading test, the luminance change was measured by using the optical devise shown in Fig. 1.

Before the experiment was carried out, surface of panel was divided into many parts like matrix as shown in Fig. 2. After the LCD module had been warmed up, display was switched to white state in 100-grey level and luminance of each divided part of panel surface through a shielding plate with a diameter of 1 mm was measured by using a luminance measurement CA210, as shown in Fig. 1. Then the panel was moved from backlight and put on a hard stage to apply a tip pressure on each divided part. The counterweights used to apply tip pressure are made of stainless steel and in a pillar shape with a contact area of 1 cm^2 on the bottom marked by a red circle as shown in Fig. 3. Pressures of 1 to 8kgw/cm^2 were applied by using these specific counterweights and each pressure was repeated five times on five divided parts of panel. Three types of test panels, T1 to T3, with different photospacer designs were used as samples in this experiment. Thereafter, the panels combined with backlight and luminance of each divided area was measured in the same way like before pressure applied test. After performed the tests described above, optical microscope and surface profiler were used for observing microstructure and measuring the height change of photospacer.

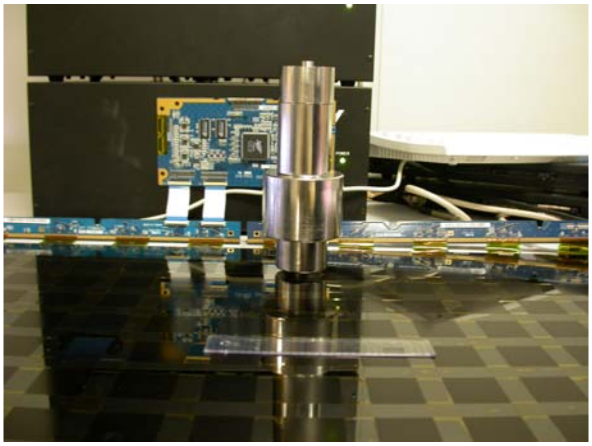

Figure 2. Photograph of testing procedure.

Figure 3. Photograph of counterweight.

Result and Discussion

The relationship between compressive stress supplied from the specific counterweight and luminance decay is shown in Fig. 4. The compressive stress versus the height change for photospacer is shown in Fig. 5. It can be seen in Figs. 4 and 5, the lumiance decay, ΔLu, represents the luminance difference between before and after test and the photospacer height reduction, Δh, represents height difference between loaded area and adjacent area after test. As shown in Figs. 4 and 5, the luminance decay and photospacer height reduction increased exponentially along with the increases of the compressive stress. By comparing with the T1 to T3 data, there is a minimum height reduction for photospacer of T3 than the other types. It means that the T3 spacer design own an excellent cell gap stability during fingertip test. It also can be found that the luminance decay and spacer height reduction consist of the same tendency. Therefore, luminance decay can be seen as an important parameter to estimate the degree of larger than that of T1. From the Fig. 4, the luminance decay of T2 and T3 are more stable than that of T1. According to the test result, it can be believed that the photospacer damage condition. On the other hand, the black spot could be obviously identified by human eyes when luminances decay over 2cd/m^2. For this reason, the experimental result also indicated that T2 and T3 can successfully resist touch mura.

The individual photospacer size and density of T1 to T3 is shown in table 1. The photospacer density is defined as the formula shown as below:

Density = (Total photospacer area in one pixel)/(pixel area)

It can be seen in table 1, there are the same density of photospacer for T1 to T3, and the individual photospacer size of T2 and T3 are

larger size photospacer is better than smaller one when in the same density arrangement.

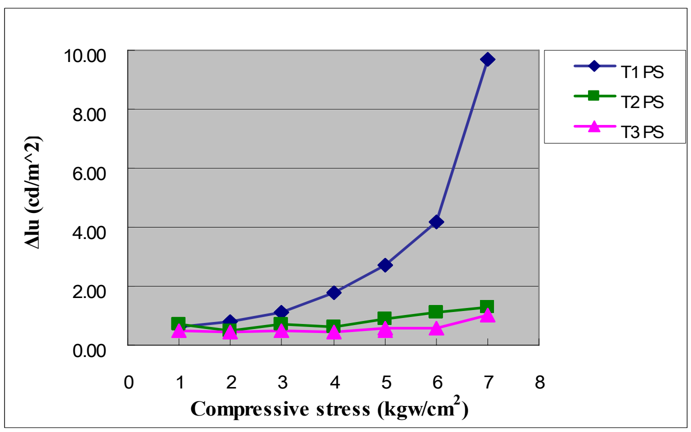

Figure 4. Relationship between compressive stresses and luminance decays for various photo spacer designs.

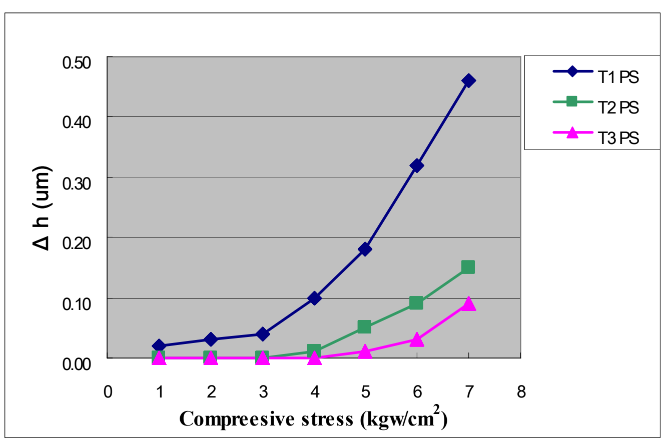

Figure 5. The relationships between compressive stresses and photospacer height reductions for various kinds of photospacer design.

Table1. Density and size of various photospacer designs.

Photospacer Design	T1	T2	T3
Density (%)	a	a	a
Size (um^2)	Small	Mid	Large

Table 2. Margin summary of liquid crystal dropping amount in ODF process for various photospacer designs.

Photospacer Design	T1	T2	T3
ODF margin (%)	1.5~2.5	7.5~8.5	6.0~7.0

The margin of liquid crystal dropping amount (liquid crystal dropping tolerance, or liquid crystal dropping process window) in ODF process for various designs of photospacers is shown in table 2. It could be found that the margin for T2 and T3 were almost 3 times compared with the T1 type.

By considering the performance for both the ODF margin and touch mura resistance between the three types of design, it can be concluded that a better cell gap stability, higher touch mura resistance, and also enough margin of liquid crystal dropping amount can be achieved by using the T3 photospacer design.

Conclusion

Recommendations include the following:

1. The measurement system was set up for evaluating the photospacer design by using luminance decay resulted from finger touch.
2. The quantitative data of touch mura has been measured for evaluating the black spot phenomena.
3. The larger photospacer will be with a better cell gap stability than that of smaller one when in the same photospacer density arrangement.
4. A better cell gap stability, higher touch mura resistance, and also enough ODF margin could be achieved by using the T3 photospacer design.

References

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