

Swipe Mura in LCD Panel and Its Correlation with the Panel Shape

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Abstract

Swipe mura is known to occur in LCD panels both in IPS/FFS and VA modes. This mura is generated when one swipes the surface of a vertically placed panel such that an applied force continuously induces a local bend. After the swipe, the mura stays visible along the swipe direction, until a light tapping on the panel surface makes it disappear, indicating a temporal/metastable shape change being the culprit. Corning acquired a new capability with which we can capture a slight shape change in vertically placed LCD panels (up to 75”) and at the same time capture a brightness distribution. With this new tool, we investigated the mechanism and the optics of the swipe mura.

Author Keywords

Mura; LCD panel; Stress Optical Effect; Shape; Curvature; Stokes Vector; Buckling

1. Introduction

A light leakage in a dark state, Mura, is known as the main visible artifact in LCD panel. It is caused by a stress in display substrate glasses which leads to a birefringence [1]. Corning has been investigating mura for many years that resulted in multiple publications [1, 2, 3]. We recently acquired a new capability, where the shape of a vertically placed panel (up to 85” diagonal) can be captured with a high accuracy by Phase Measuring Deflectometry (PMD), FIG.1(a). At the same time, we can capture mura without disturbing temporal panel shapes, FIG.1(b). This is a perfect tool to investigate swipe mura. The swipe mura is a light leakage that appears in both IPS/FFS and VA modes when the screen of a vertically placed panel is “swiped” with a force. A continuously moving point of force application results in mura, which remains visible until the panel +surface is tapped. This observation indicates the temporal shape change (metastable shape) and resulting stress field is the culprit of the mura. In this paper, we investigate the mechanism and optics of swipe mura in relation to the panel shapes for both IPS and VA mode LCD panels.

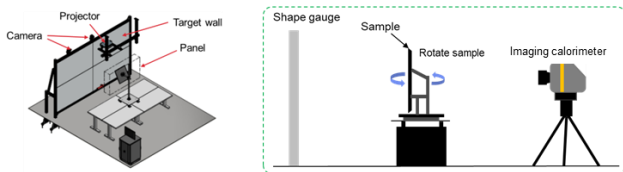


FIG. 1 (a) The PMD setup for a vertically placed display panel and (b) the laboratory setup to capture mura and an associated shape.

2. Panel Shape Measurement Capability

We have setup panel shape measurement equipment in our lab, as shown in FIG.1(a). A panel is placed vertically during shape measurements, mimicking the panel placement in a real application. The measurement principle of this equipment is based on phase measuring deflectometry (PMD) [4]. Sinusoidal patterns are projected to a target wall and then reflected to a test object (a panel surface). Since specular surfaces reflect incoming light in only one direction, the reflected pattern from the object under test can be observed by two digital cameras (stereo deflectometry setup). When there is a slope variation at a specific point of the test

surface, sinusoidal patterns will be distorted and captured by cameras, from which a shape is constructed. The spec of this equipment is shown in Table 1. The maximum size that can be measured is 85” TV panel. The sample surface curvature is measured in the unit of diopter (dpt) or milli diopter (mdpt), where $dpt = m^{-1}$ or $mdpt = 1/(1000m)$. The measurement accuracy of curvature is $< 20mdpt$.

Specification of the Shape Measurement Instrument		
Sample surface reflection requirement	>4%	
Test object size	Min: 0.1m X 0.1m Max: 75” TV (1.7m X 0.95m)	
Local flatness accuracy	30cm area	~40 μ m
	10cm area	~10 μ m
	5cm area	~2 μ m
	1cm area	~1 μ m

Table 1. Specifications of the Shape Measurement equipment

3. Experiment

We selected both IPS and VA panels for our investigation. Each panel went through the following three-step measurement:

- Measurement of a panel “original” shape

A panel shape is captured while the panel is hung from a metal bar at two ends via double sided tapes, FIG.2(a).

- Shape measurement when a panel is mounted on a TV frame

We attached a panel to a TV backlight unit (BLU) frame using a double-sided foam tape normally used in the industry, FIG.2 (b). The module (panel + TV frame) is attached to the rotatable stage, FIG.1(b). We capture the brightness distribution (i.e., mura) of the panel in a dark state, then rotate the stage to capture a before-swipe shape.

- Swipe and brightness/shape measurement

Following step b), we push and swipe the panel surface (either a horizontal, *H-swipe*, FIG.2(c) or a vertical, *V-swipe*, FIG.2(d) direction), and this is followed by a brightness/shape measurement. The applied force during push & swipe is ~25N.

The above steps are repeated four times for each panel to evaluate the measurement reproducibility.

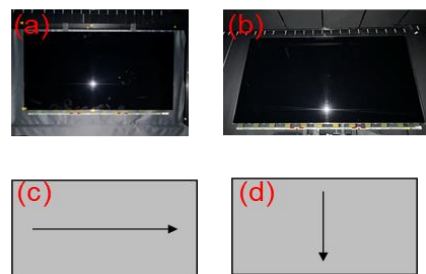


FIG. 2 (a) A panel “original” shape measurement setup. (b) A panel is attached to a TV backlight unit through a frame. (c)/(d) swipe directions used in our experiment.

4. Results and Discussion

4.1 Panel original shape

Panel original shapes of IPS and VA panels are shown in FIG.3. While the VA panel shows a consistent shape, with the IPS panel, the 4th measurement shape is different from that of preceding three. This is due to the fact that 65” panels are flexible, and their shapes can change during hanging. After mounting, panels are fixed by the BLU frame, therefore, the shape measurement shows better reproducibility, as shown in FIG.4.

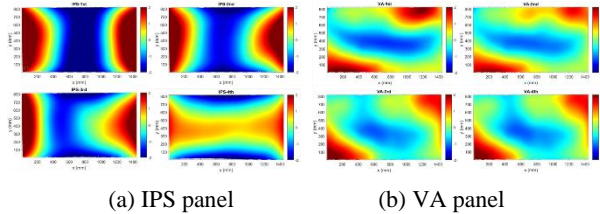


FIG.3. The panel original shape reproducibility

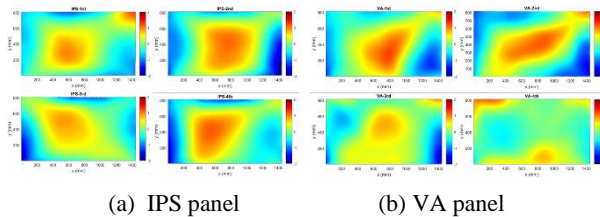


Fig 4. The panel shape reproducibility after mounting to BLU

4.2 Panel mura and shape after swipe

For the IPS panel, after H-swipe, there is a clear vertical curvature (kyy), while no strong horizontal curvature (kxx) was observed after V-swipe, top of FIG.5. The mura after V-swipe is more obvious than that after H-swipe. The latter is visible at the normal and a slightly oblique direction.

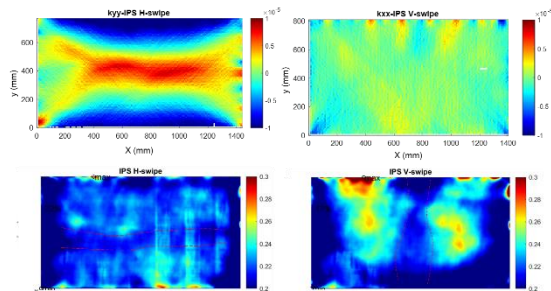


Fig 5. The curvature (top) and mura (bottom) of an IPS panel after H (left) and V (right) swipes. Mura part is outlines by dotted red lines.

For the VA panel, we observed both vertical curvature (kyy) on the panel after H-swipe and, while less obvious, kxx generated by V-swipe. In contrast to IPS, the swipe mura is not visible at the normal direction but becomes obvious at oblique directions, see Fig 6. The vertical swipe mura is more obvious in VA compared to IPS, perhaps related to the “sharpness” in kxx.

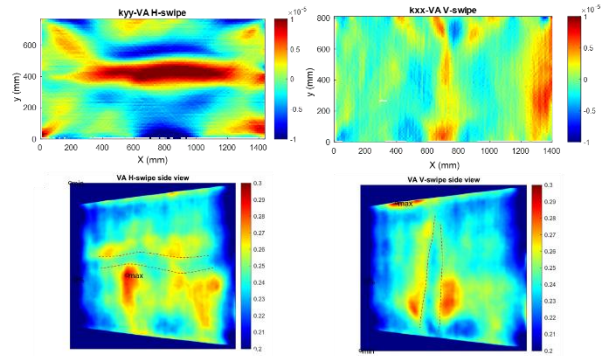


Fig 6. The curvature (top) and mura (bottom) of a VA panel after H (left) and V (right) swipes. Mura part is outlined by dotted red lines.

After the swipe to induce mura, we tapped the surface of the panel, and observed that:

- Both H and V mura in IPS and VA modes quickly disappears
- The panel goes back to the original shape, e.g., FIG.3, and hot spots in curvature maps (kxx, kyy) vanish.

5. Simulation

In order to understand the basic mechanism and the difference between the IPS and VA panels, we built a simple FEA model with ANSYS. From stress output, we calculated the outgoing polarization state in terms of Stokes vector at various viewing angles. FIG.7 shows the model in ANSYS where the panel is subjected to a swipe action. We first calculated the retardation and its optic axis direction from the stress tensor map of the CFA (front) and the TFT (back) glasses. With this information, we setup up an optical propagation model using a 4X4 matrix to compute output Stokes vector components. Here, LC is assumed to be a simple A-plate and a C-plate for IPS and VA modes, respectively. In both cases, the panel total retardation was set at 300nm @ . In FIG.8, we show the Stokes vector map of the normal viewing IPS, and normal and oblique viewing of VA mode. In the IPS case, swipe mura is signified mainly by the pair of negative/positive S3 components. The VA panel viewed at normal direction shows very little mura. i.e., $S1 \cong 1$. At the oblique direction, although lesser intensity than IPS case, swipe mura becomes visible (verifying our observation), in terms of +/- S2. Trace on the Poincare sphere for each case are schematically shown in FIG.9 for the following cases: a) IPS normal view b) VA normal view and c) VA oblique, rotated 40°. At normal viewing direction, stresses induced by the swipe deformation in the TFT and CFA glasses are coupled by A-plate in IPS case, while stresses are not coupled in VA case, thus no mura. However, the oblique view in VA does have mura due to the facts (1) propagating rays pick up retardation from C-plate, and (2) the optic axis of glass stress retardation, diagonal (@ 45° and 135° with respect to a panel, are no longer perpendicular. We experimentally confirmed the pair occurrences of +/- S3 and +/- S2 in IPS swipe mura using a combination of linear/circular polarizers and imaging colorimeter.

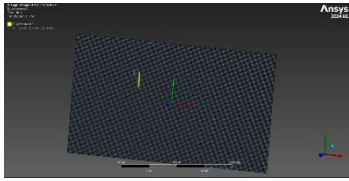


FIG.7 ANSYS model for the swipe mura

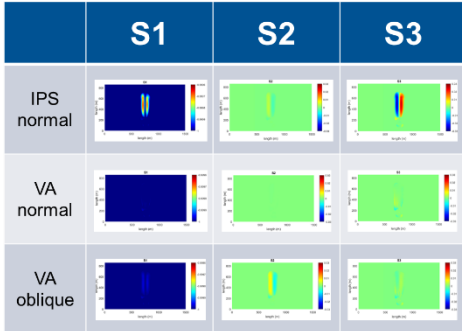


FIG.8 Stokes vector components of output light from swipe mura

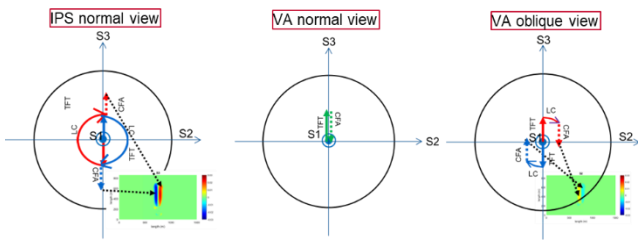


FIG.9 Trace on Poincare sphere for swipe mura

6. Summary and Impact

With this new capability Corning developed, we can capture the shape and the mura of vertically placed display panels at the same time. Using this unique tool, we studied the swipe mura

mechanisms in IPS and VA panels, the correlation of mura with the panel shape, and its optical process. The swipe on a panel resulted in the temporal shape change and stress field within the panel, which affects the outgoing polarization state of propagating light. For the IPS case, the swipe mura is signified mainly by the pair of +/- S3 component. For the VA case, while essentially no mura is seen at the normal direction, swipe mura becomes visible in terms of +/- S2 at oblique directions, although lesser intensity than IPS case.

Through this study, we came to understand the swipe mura mechanism. This learning will help to further investigate and improve other mura behavior caused by panel shape changes, in applications such as curved monitors and automotive display modules.

7. Acknowledgements

We would like to acknowledge various contributions from our colleagues: Yue Cao, David Hwang, Lobo Liu, John Tang and Ray Greene.

8. References

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