45.3: Thin LCD Substrates Reduce Edge-Light Mura

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Abstract

Reducing LCD substrate thickness from 0.7 mm to 0.5 mm improves edge-light mura from glass thermal-stress birefringence by 26%. Sub nanometer (nm) resolution retardation measurements were performed on 1.1, 0.7, 0.5, 0.4, 0.3, and 0.1 mm thick substrates of width 482 mm and a height of 305 mm with an LCD edge-light and are in good agreement with the stress optic law.

1. Introduction

The purpose of this paper is to quantify the effect of and to provide a model for the way thinner TFT/CF substrates improve the substrate contribution to edge-light mura on LCD displays. Figures 1 and 2 are CCD pictures of a commercial TN LC mode monitor and a commercial VA LC mode LCD-TV in black fields that show distinctive edge-light mura. These images were taken with a Radiant Imaging Inc. model PM-1423F camera.

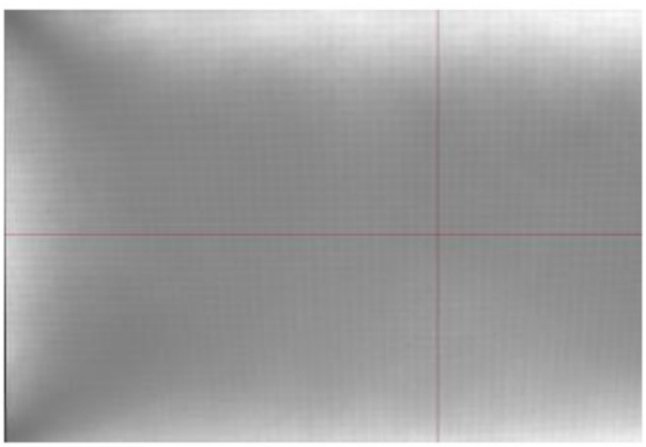

Figure 1. CCD picture of a TN LC mode monitor in black field shows distinctive edge-light mura.

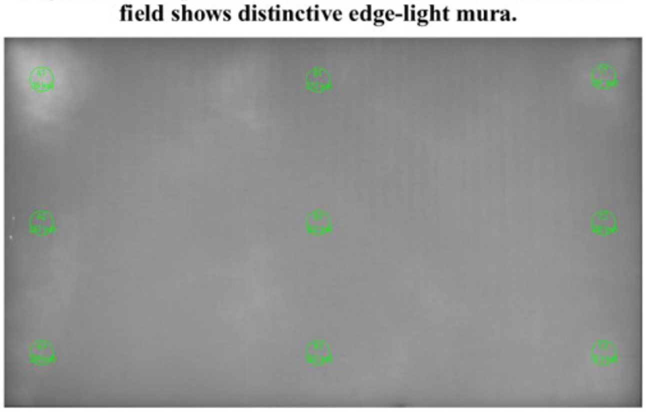

Figure 2. CCD picture of a VA LC mode LCD-TV in black field shows distinctive edge-light mura.

A significant component of this mura is created by the stress in the panel glass due to the non-uniform temperature distribution from the heat of the edge/backlight. This stress creates distinctive smile-shaped retardation patterns on the edges of the glass. The TN polarizers at 45°/135° select the 0°/90° retardation component of thermal stress induced retardance as shown in Figure 1 as "H-band" mura on the edges. The VA polarizers at 0°/90° select the 45°/135° component of thermal stress induced retardance as shown in Figure 2 as "white corners".

The experience of our lab is that, for typical LCD displays, the magnitude of this thermal stress-induced retardance can be of nm order. This is indeed significant compared to the black field panel retardance, typically on the order of a few nm's. Reference [1] gives a more detailed analysis of glass retardance effects on large LCD's. References [2] and [3] are recent works about a system-level approach to these issues and analysis of the pressure sensitive adhesive (PSA) contributions to this issue.

2. Experimental

Figure 3 is a picture of our experimental setup. This consists of a vertical xy stage of approximately Gen 4 size and a Hinds Instruments custom-made retardance gage with generator and analyzer heads based on photo-elastic modulator (PEM) technology [4]. For these measurements, we use a 4 mm diameter spot of 633 nm wavelength to measure the retardance of the glass and an xy step size of 5 mm. Also shown are the edge-light and electronics from a commercial LCD monitor that is mounted to the glass.

For these measurements we measured the various thicknesses of EAGLE XG® glass substrates with the edge-light off and on (warmed up) to be sure that the glass's intrinsic retardation was not significant. It should be noted that the 1.1 mm thick glass was Corning 1737 glass, not EAGLE XG. However, the precision of these measurements to the relevant material parameters of coefficient of thermal expansion (***CTE***), Young's modulus (***E***), and stress optic coefficient (***SOC***) are not significantly different. It also should be noted that in a real LCD display, the edge-light is directly coupled to a typical PMMA waveguide behind the panel - not directly to the glass as in our setup. Nevertheless, we believe our configuration is representative and illustrative of the phenomena heat on the edge of the panel glass.

3. Physical Model of Thermal Stress Induced Retardance in Glass

We start with the stress optic law [5] from the standard theory of photo elasticity with t as the thickness, R as the retardance, σ_{11} as the first principal stress, and σ_{22} as the second principal stress:

$$R = SOC * t * (\sigma_{11} - \sigma_{22}) \quad (1)$$

Using Hooke's law, $\sigma = \epsilon * E$, and $\epsilon = CTE * \Delta T$, where ΔT is the temperature difference equation (1) becomes:

$$R = SOC * E * CTE * \Delta T * t \quad (2)$$

SOC, ***E***, and ***CTE*** for EAGLE XG glass are published in the publically available material data sheet. Their product is $\frac{0.56\ nm}{mm\ °C}$.

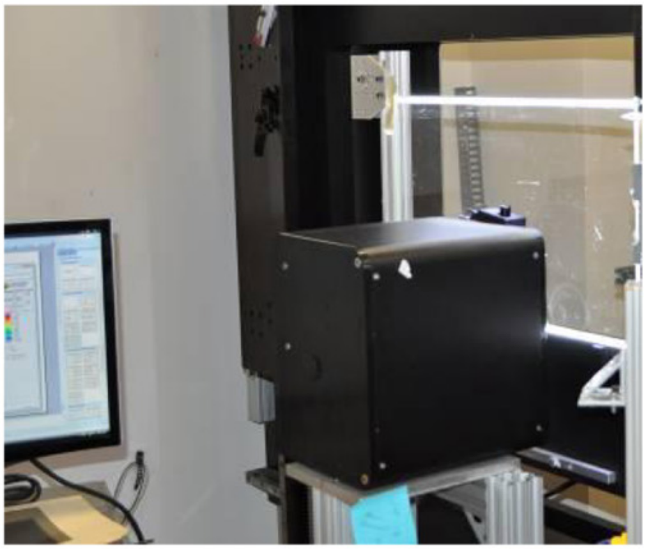

Figure 3. Experimental setup.

4. Results

4.1. Total Retardance

Figures 4(a) and 4(b) give the total measured retardation magnitude for the edge-light in the off and on configurations for 1.1 mm thick glass cases respectively. The same intensity scale is used for both figures. These figures are representative of the results for the other measurements performed for edge-light in the off/on configurations for 0.7 mm, 0.5 mm, 0.4 mm, 0.3 mm, and 0.1 mm thicknesses. It should be noted that in our mounting configuration the right side of the glass was heat sunk to a vertical aluminum plate and the left side was not. This explains the left to right asymmetry and is consistent with our model.

4.2. TN-filter polarizer configuration

Figures 5(a) and 5(b) give the transmission calculated from the measured retardance and simulated TN configuration polarizers for the edge-light in the off and on configurations for 1.1 mm thick glass cases respectively. The same intensity scale is used for both figures. Again, these figures are representative of the results for the other measurements performed for edge-light in the off/on configurations for 0.7 mm, 0.5 mm, 0.4 mm, 0.3 mm, and 0.1 mm thicknesses. Note the characteristic “V” (vertical) and “H” (horizontal) band mura on the left and top of Figure 5(b). These features appear quite similar to the edge mura features in the TN-LCD monitor of figure 1.

4.3. VA-filter polarizer configuration

Figures 6(a) and 6(b) give the transmission calculated from the measured retardance with simulated VA configuration polarizers for the edge-light in the off and on configurations for 1.1 mm thick glass cases respectively. The same intensity scale is used for both figures. Again, these figures are representative of the results for the other measurements performed for the edge-light off/on configuration for 0.7 mm, 0.5 mm, 0.4 mm, 0.3 mm, and 0.1 mm thicknesses. Note the characteristic “white corners” at the top left corner of the edge-light on Figure 6(b). These features appear quite similar to the corner mura features in the VA-LCD-TV of figure 2.

4.4. Retardance vs. Glass Thickness

Figure 7 is a summary plot of the maximum corner linear retardance in nm for all the glass thicknesses for the edge-light in the on condition, and a linear fit to the data. The fitted line is in good agreement with equation (2). Back solving the slope for ΔT from equation (2) gives $7.1°C$, a result consistent with other temperature measurements we have made on LCD displays.

5. Conclusions

Thin glass provides a significant improvement to reduce edge-light mura from thermal stress induced retardance in panel glass. We have provided both a model and measurements in a realistic situation to support this.

6. Acknowledgements

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7. References

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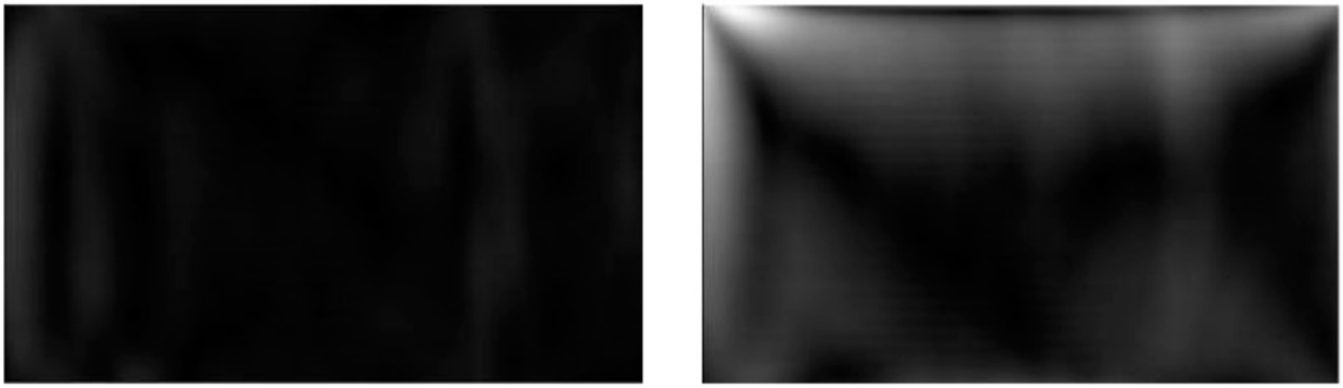
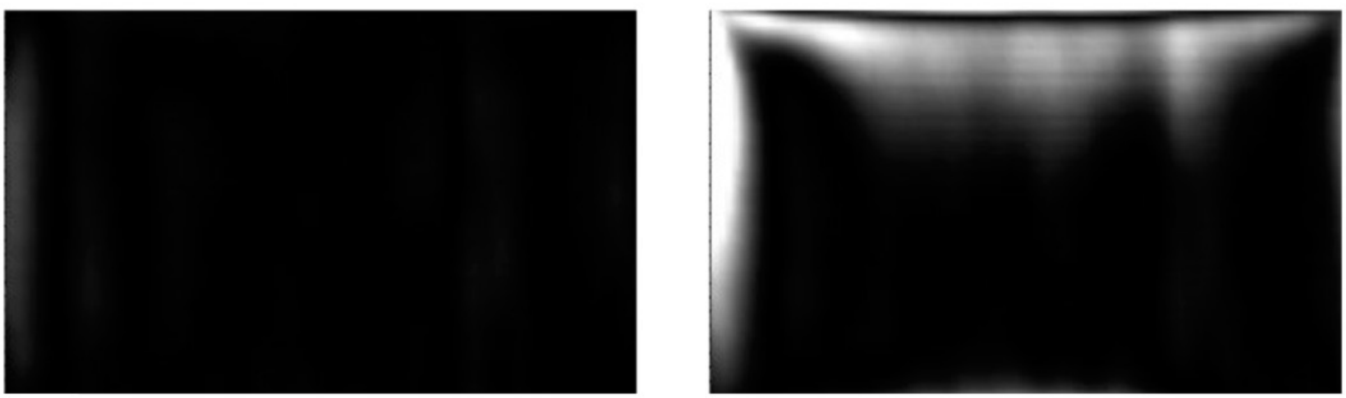


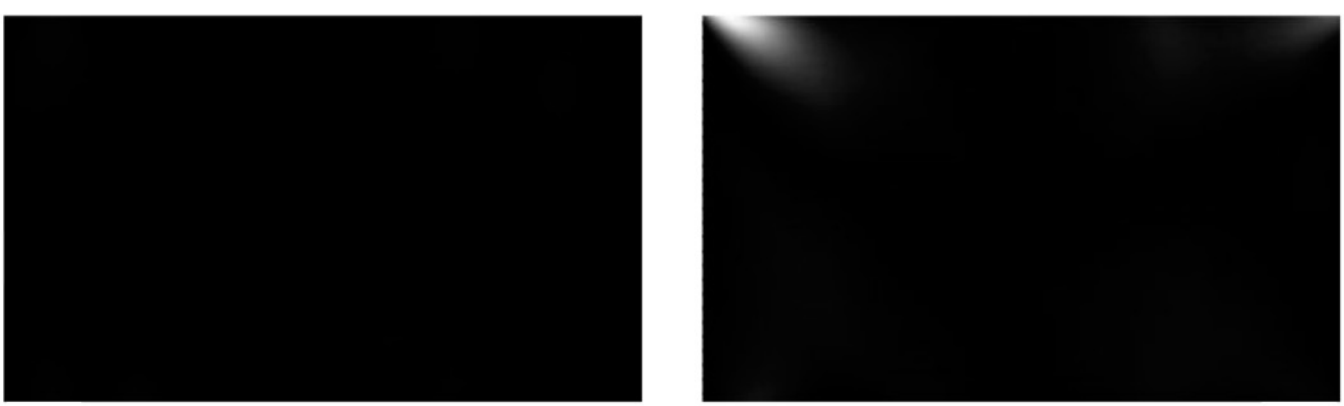
(a) (b)

Figure 4. Total retardance magnitude: (a) edge-light off, (b) edge-light on.



(a) (b)

Figure 5. TN-filter transmission: (a) edge-light off, (b) edge-light on.



(a) (b)

Figure 6. VA-filter transmission: (a) edge-light off, (b) edge-light on.

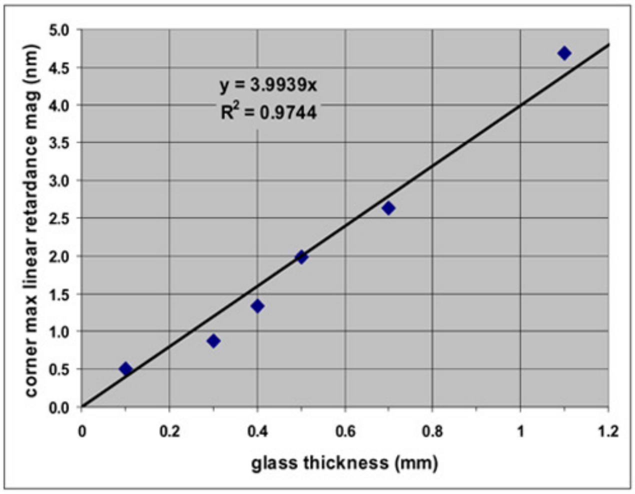


Figure 7. Maximum thermal stress retardance from edge-light vs. glass thickness.