Image Sticking Evaluation Methods for OLED TV Applications

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Abstract

In this paper, we propose a new method for measuring image sticking of an OLED display using a human visual test. We determined that the perceptual image sticking threshold is 2% of luminance difference at 200 nits and 1% at 100 nits, respectively. Color shift must also be considered when evaluating image sticking, as a $\Delta(u', v')$ *shift of just over 0.002 can be recognized regardless of background brightness. Perception of image sticking is affected by the background level, test pattern, and ambient illumination conditions. The evaluation standard must consider both luminance variation and color shift simultaneously.*

1. Introduction

Organic light emitting diode (OLED) displays are considered to be a possible replacement for TFT-LCDs due to their low power consumption, vivid color, fast response time, wide viewing angle, and slim form factor [1, 2]. Recently, the market for OLED displays has undergone remarkable growth, and OLED television applications have begun to appear. Sony has launched an 11-inch OLED TV, and Samsung has presented 14-inch and 31-inch OLED TV prototypes at the 2008 CES [3], as well as the world's largest 40-inch OLED TV as shown at the 2008 FPD International show [4].

As OLED displays grow in size, it is naturally easier to detect image quality issues. However, an image sticking specification has not yet been determined for large sized displays. Therefore, an objective evaluation method, followed by ideas for improvement of image sticking, will be required so that OLED technology can deliver excellent image quality in the large sized display market.

2. Experiments

In this study, we conducted four different types of experiments. Experiments #1-3 were carried out using a 14.1-inch OLED panel to test perception of artificial defects consisting of different background conditions, shapes, sizes and color, as shown in figure 1. The final visual experiment was to determine the effect of ambient environment by controlling illumination conditions using an 11-inch OLED TV. In all tests, distance from the panel to participants was ~30 cm. Experimental conditions are summarized in table 1.

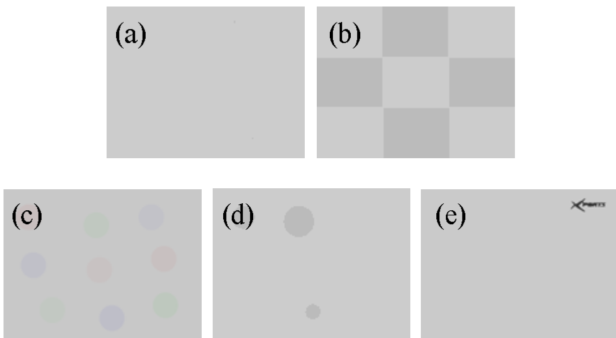

Fig. 1 Examples of artificial defects used in the experiments: (a) line defects; (b) stitch defects; (c) circles with different colors; (d) circles with different sizes; (e) TV broadcasting logo

The purpose of the first experiment was to determine how many participants could distinguish artificial defects with 100 nits and 200 nits background panel settings. The second and the third experiments were designed to compare different size and color effects on defect perception. The final test was to understand environmental effects by changing the illumination conditions.

Table 1. Summary of visual test conditions

	Experiments 1-3	Experiment 4
Panel size	14.1-inch OLED	11-inch OLED TV
Participants	35 people	20 people
Ambient illumination	400 lux in office	0 lux / 150 lux / 500 lux (D65)
Distance from panel to participants	30 cm	
Background luminance (full white)	200 nits (255 gray) / 100 nits (174 gray)	150 nits (255 gray)
Pattern shape	Line / stitch / circle (different color and size)	TV broadcasting logo image
Circle size (diameter)	0.2 mm / 5 mm/ 10 mm / 20 mm	-
Gray level of pattern	Δ1 to Δ3 gray level	Δ1 to Δ7 gray level
	Reduction compared to background luminance	
Color of pattern	Reddish / greenish / bluish	
	Vary the gray scale about Δ1 to Δ3 gray	Vary the gray scale about Δ1 to Δ7 gray

The illumination condition is a very important parameter for determining the specification of image sticking for TV, but to date there have been no reports of this effect. In the final experiment, we chose three conditions: 0 lux, 150 lux and 500 lux.

3. Results and discussion

In the first experiment, the background was kept at gray level 255, while the pattern's gray level was reduced by 1 to 3 gray levels below the background. This reduction corresponded to a luminance change from 1% to 3%. When luminance difference of the defect was more than 2% below the background, the defect was more easily perceived against the 100 nits background compared to the 200 nits background as shown in fig. 2(a). This phenomenon can be explained with Weber's law, which is usually described by stating that the smallest detectable difference in the change of a stimulus is proportional to the magnitude of the original stimulus. The law is usually expressed by the equation $(\Delta I) / I = k$, where ΔI is the difference threshold in physical magnitude, I is the magnitude of the original stimulus, and k is the Weber fraction, which is a constant for any type of sensation but one which varies from one type of sensation to another [5]. Once again, in order to have a similar influence at 200 nits, a higher luminance difference is necessary.

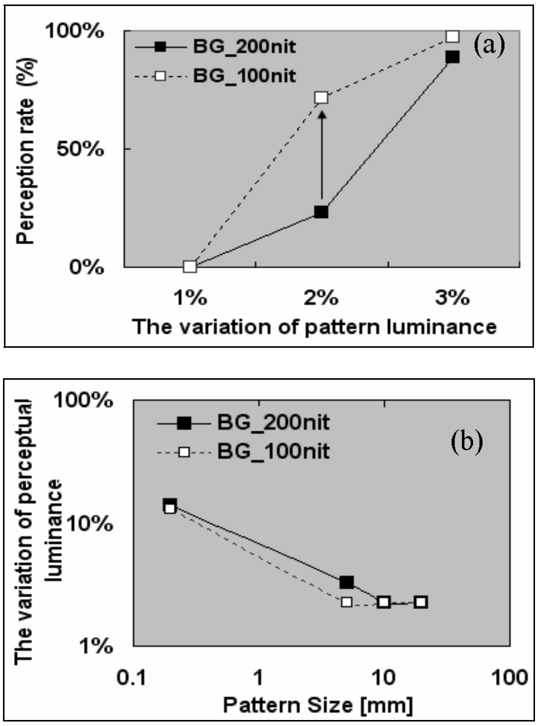

Fig. 2 (a) Variation of pattern luminance and perception rate, (b) pattern size and the variation of luminance

In the second experiment, we showed that there is a relationship between defect size and perceived level of luminance change. When the defect size increases, it is more easily perceived. For example, a 0.2 mm defect was perceivable at 13.79% luminance difference. However, larger defects, such as 5 mm and larger, could be perceived with smaller luminance change. The 5 mm defect was detected at 2 to 3% luminance difference, and defects greater than 10 mm could be perceived at 2% luminance difference regardless of the background luminance level.

The third experiment helped to quantify human visual system perception of color shift. Color shift is important in an assessment of image sticking due to differential aging of red, green, and blue OLED emitters. As shown in table 2, gray level of each reddish, greenish and bluish defect patterns has been changed in order to perform various tests of Δ(u', v') and ΔL. To create a reddish defect (for example), the blue and green gray levels were decreased by one or more steps.

Table 2. Correlation between the perception rate and various color patterns

Pattern Color	Gray level of pattern	ΔLum		Δ(u',v')		Perception Rate	
		200nit	100nit	200nit	100nit	200nit	100nit
Reddish	Δ1G	0.70%	0.70%	0.002	0.001	0%	29%
	Δ2G	1.44%	1.47%	0.002	0.002	34%	83%
	Δ3G	2.29%	2.28%	0.003	0.003	97%	94%
Greenish	Δ1G	0.00%	0.10%	0.002	0.001	3%	9%
	Δ2G	0.40%	0.65%	0.003	0.003	6%	77%
	Δ3G	0.50%	1.14%	0.004	0.003	23%	80%
Bluish	Δ1G	1.19%	0.86%	0.001	0.001	0%	14%
	Δ2G	2.39%	1.96%	0.002	0.002	74%	100%
	Δ3G	3.38%	2.99%	0.003	0.004	100%	97%

From the test, perception of bluish and reddish defects was much greater than that of greenish defects because of the amount of luminance change in the display. For instance, the luminance of the greenish defect in case of a Δ3G pattern is reduced by just 0.5%. This luminance reduction compares to a drop of 2-3% in case of a reddish or bluish defect at 200 nits.

Table 3. Summary of defect perception rates at three different ambient illumination conditions

Pattern Color	Gray level of pattern	ΔLum.	Δ(u',v')	Perception Rate		
				0 lux	150 lux	500 lux
Gray	Δ1G	1.20%		0%	0%	5%
	Δ2G	2.00%		40%	45%	45%
	Δ3G	2.70%	-	55%	70%	90%
	Δ4G	3.10%		100%	100%	95%
	Δ5G	3.80%		95%	100%	95%
Reddish	Δ1G	2.05%	0.002	0%	0%	0%
	Δ2G	2.56%	0.001	5%	20%	10%
	Δ3G	3.91%	0.001	60%	65%	80%
	Δ4G	4.18%	0.003	60%	75%	70%
	Δ5G	4.87%	0.004	85%	100%	100%
	Δ6G	5.17%	0.001	85%	100%	100%
	Δ7G	6.30%	0.002	70%	100%	95%
Greenish	Δ1G	1.43%	0.002	0%	0%	0%
	Δ2G	1.87%	0.001	5%	5%	0%
	Δ3G	2.33%	0.002	5%	35%	45%
	Δ4G	2.56%	0.003	10%	30%	30%
	Δ5G	3.11%	0.003	40%	35%	70%
	Δ6G	3.47%	0.002	50%	75%	80%
	Δ7G	3.88%	0.003	65%	95%	95%
Bluish	Δ1G	0.85%	0.001	0%	0%	0%
	Δ2G	3.00%	0.002	0%	20%	25%
	Δ3G	3.61%	0.002	80%	90%	90%
	Δ4G	3.61%	0.003	70%	85%	85%
	Δ5G	5.11%	0.001	95%	100%	100%
	Δ6G	5.90%	0.002	95%	100%	100%
	Δ7G	6.23%	0.001	100%	100%	95%

The final experiment was conducted to test defect perception under different ambient illumination conditions by controlling the gray level and changing color of the pattern. As noted above, three different ambient illuminations were selected: 0 lux, 150 lux and 500 lux. Perception rates are summarized in table 3 and plotted in fig. 3.

As shown in fig. 3, all pattern types showed the same trend in that when illumination conditions are increased, then the perception rate is also increased. For example, the Δ 6 gray greenish pattern could be perceived by just half of the participants at 0 lux, but the perception rate dramatically increased at 150 lux. That means that ambient illumination is an important variable because its level can change the threshold of perception. We conclude that ambient illumination is a key parameter that must be included when measuring or specifying TV image sticking performance.

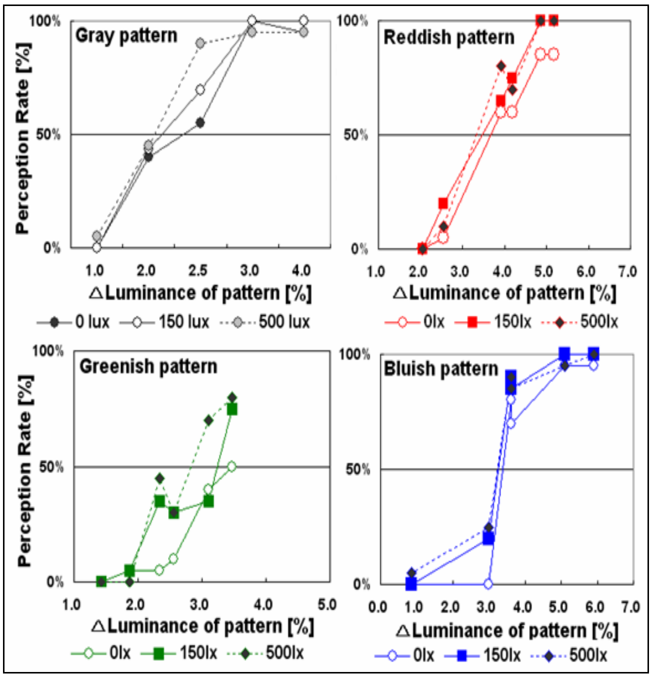

Fig. 3 Perception of gray, reddish, greenish and bluish patterns under three different ambient illumination conditions

In conclusion, it is possible to perceive luminance differences of over 2% and Δ(u', v') changes greater than 0.002 when these defects are viewed against a 200 nit background. Against a 100nit background level, luminance differences of over 1% are perceivable, but perceptual changes in Δ(u', v') are the same as those against a 200 nits background. Ambient illumination conditions have also been found to have a significant influence on the perception of image sticking.

4. Summary

"Image sticking", also known as image retention or burn-in, is an important issue for emissive displays. In order that OLED displays can deliver excellent image quality for televisions and IT products, a method which can objectively evaluate image sticking is required. A perceptual approach that considers human visual characteristics is necessary in order to develop a proper method for evaluation of image sticking. Until now, most OLED image sticking evaluation metrics have been focused on mobile sizes. If the same metrics are applied to larger screens, they may be insufficient to accurately describe the visual impact. Therefore, in this paper, we have found more suitable image sticking measurement methods for large size (>11-inch) displays by human perception studies. We have found that if the luminance and color variation of a defect is changed by more than 2% and 0.002, respectively, against a 200 nit background, then it is possible to perceive the defect. Also, at a 100 nit background, luminance change can be perceived at only 1% difference, but sensitivity to color variation is the same as in the case of the 200 nit background luminance condition. Moreover, the environment also affects characteristics of the human visual system, such that observers more easily perceive defects at higher illumination conditions.

It is expected that this research will form the basis for objective evaluation of human visual sensitivity to OLED image sticking properties. Future efforts will also be given to standardization of these metrics.

5. References

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