New Analysis Method of Image Sticking of LCD

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Abstract
In this paper, we present the new method of analyzing image sticking phenomenon on the liquid crystal display (LCD), which is one of the main problems deteriorating image quality. We have first categorized the main factors of the image sticking and then simulated the proportion of these factors by using the experimental data. We expect that the new analyzing method can be used to understand the basic mechanism of the image sticking and to solve the chronic problem of LCDs.

Author Keywords
LCD, Image sticking, VA mode

1. Introduction
Image sticking or image retention phenomenon can be observable after aging(display fixed image for a long time). For example, if we display Fig. 1 (A) image certain time, then we could see the Fig. 1 (B) image even though try to display uniform gray image. Because this phenomenon looks like the previous image to be stuck on display, we call this as image sticking. We call this type (Fig. 1) of image sticking as plane image sticking.

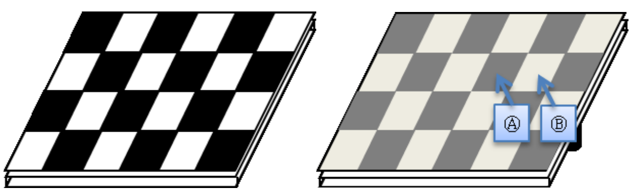


Figure 1. (A) Aging image (B) Plane type Image sticking Displayed image after aging

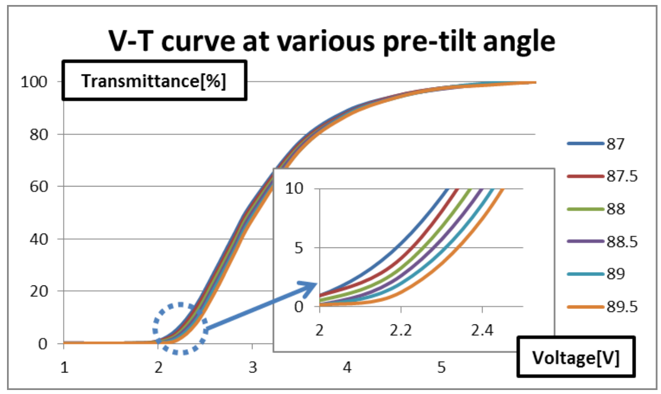
In some cases, we could see line (or edge) type image sticking instead of plane image sticking [1] [2]. But line image sticking has different causes and analysis method. Therefore we focus on the analysis method of plane image sticking in this paper.

Not only many causes affects this phenomenon but also it is difficult to know how much each cause effects on this. In this paper, we would like to show how to calculate the effects of three causes of image sticking especially on the Vertical Alignment (VA) mode LCD.

It is hard to say that this method can be applied to analyze image sticking causes of other LC mode by this way. But it will serve as a guideline for analysis.

2. Causes of Image Sticking
Causes of image sticking can be categorized by the change of 1) Pretilt angle (ΔPretilt), 2) Residual-DC (ΔR-DC) and 3) VHR (ΔVHR). First of all, we will explain how each factor could be a cause of image sticking.

2-1. Pretilt angle
LC in Patterned VA[3] mode LCD aligned vertically at alignment layer (Pretilt angle is 90˚). But LC in optical aligned VA mode or Polymer Stabilized VA (PSVA)[4] mode don't align vertically based on the alignment layer. The V-T curve of VA mode LCD depends on the Pretilt angle like following Graph 1.



Graph 1. The V-T curve at various Pretilt angle. Simulated by Twist Cell Optics Ver. 4.1

Therefore if the Pretilt angle between (A) and (B) area are different, it is a cause of image sticking [5].

2-2. Residual DC (R-DC)
LC and alignment layer materials that generally used in TFT-LCD are electrically neutral. But one of them or both have localized electricity by some reasons, this electricity makes an internal electric field. Then effective electric field in LC layer will be increased or decreased whether the direction of applied electric field and that of an internal electric field are matched or not.

If (A) and (B) area's R-DC values are different, the total strength of electric field (E_{total}) at (A)positive and (B)negative frame are not same like Figure 2. Therefore, the transmittance after aging would be changed from the initial condition.

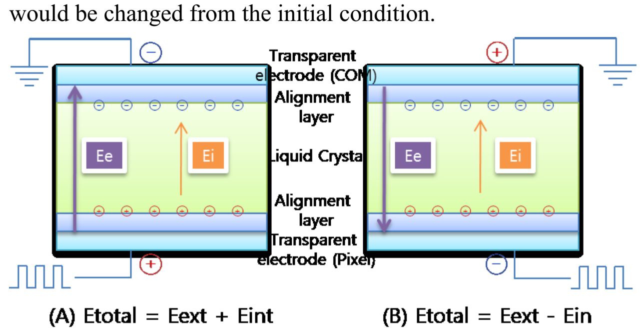


Figure 2. Internal (R-DC in LC or PI layer) and external electric field (electric field between Transparent electrodes)

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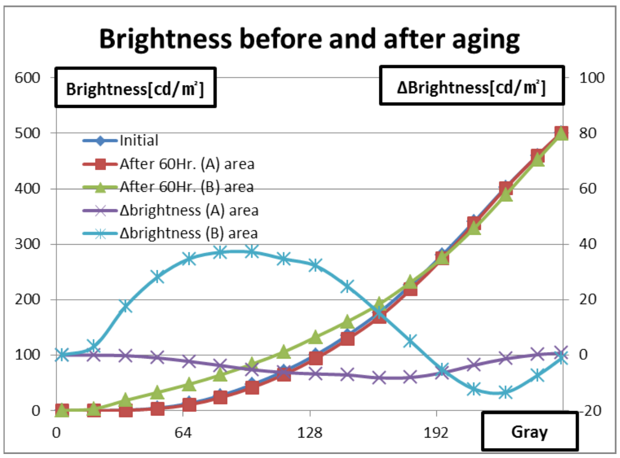
2-3. Voltage Holding Ratio (VHR)

When we set OFF on the gate electrode, TFT could isolate LC and storage capacitor's charge from leaking. Therefore VHR which is how much charge in the cell could be kept during the frame time is very important in TFT-LCD. If the VHR is low, effective electric field applied in LC will be decreased. Therefore some pixel's VHR drops by any reasons, their transmittance should be decreased than other pixels [6].

In general, the definition of VHR restricts only for the LC and alignment layer. But in this paper, we would like to use this terminology for how much charge is kept from leaking in the entire pixel including TFT, LC, and storage capacitor etc.

3. Transmittance change after aging

Graph 2 shows the measurement result of γ–curve before and after aging, at each (A) and (B) area of Figure 1. The difference between two area's γ-curve means the image sticking during the aging period.



Graph 2. Gamma curve before and after aging at (A) and (B) area at Figure 1. Aging time 60Hrs.

4. AC and DC image sticking

AC causes of image sticking have related with frame frequency, although DC causes (just like the internal field in Fig. 2) have not.

Therefore AC causes increase or decrease transmittance of both positive and negative polarity. But if DC causes increase the transmittance of positive polarity, then the transmittance of negative polarity will be decreased.

If the ratio between these two voltages is changed, the transmittance will be changed. Although the average value of the induced voltage in LC at positive and negative frame are maintained.

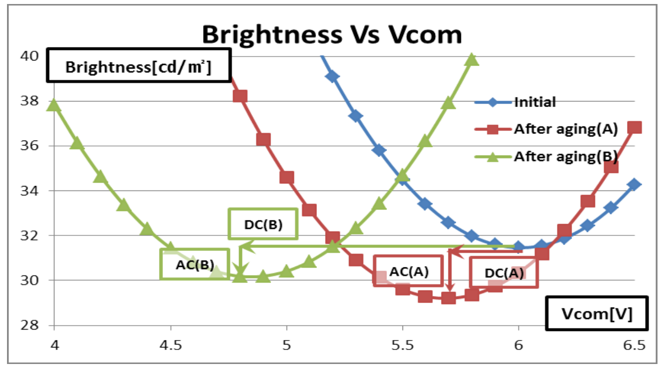
1) If the response time of LCD is fast enough, the temporal average of transmittance is a just average value of transmittance at the positive and negative frame.
2) Otherwise, it is decided as RMS value of above two values.

4-1. Transmittance dependence on Vcom voltage

As mentioned before, if there are change of R-DC in pixel(eg. the internal field at Fig.2 changed) effective voltage induced in the pixel will be changed. This effective voltage can be compensated by changing the Vcom voltage. Therefore if DC image sticking occurs V-com transmittance curve will be moved horizontally, while AC image sticking will be moved vertically.

It should be noticed that in some cases, the V-T curve at area (A) can change more than that of area (B).

4-2. Separation of AC and DC image sticking



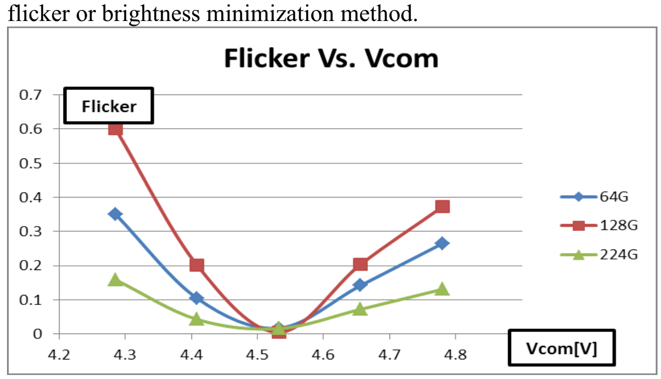
Graph 3. Transmittance dependency of the Vcom voltage before and after aging period.

The Vcom-Transmittance dependency of at initial and after 60Hr. aging at area (A) and (B) was showed in Graph 3. From this relationship, both (A) and (B) area have AC image sticking as well as DC image sticking. Although each area has the different contribution to AC and DC image sticking.

Therefore we should separate out AC and DC causes at the beginning. Because if we change Vcom value of panel, the effect on image sticking due to DC causes be changed or even be vanished at the typical Vcom value.

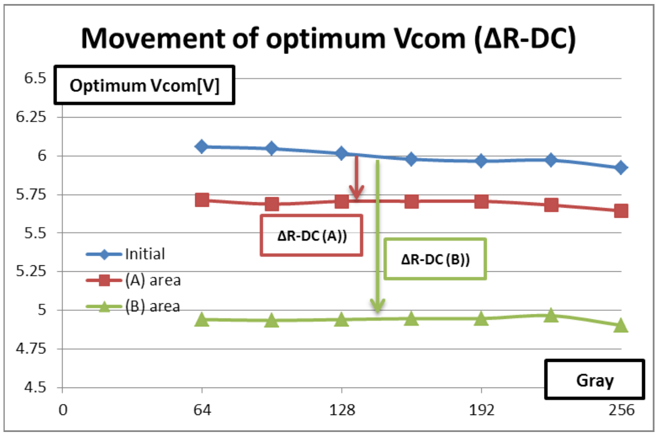
5. Image sticking due to ΔR-DC

To obtain the transmittance differences due to ΔR-DC, it is necessary to know how much R-DC is changed. To know this, we should measure the value of "optimal Vcom" voltage before and after aging. The Optimal Vcom voltage could be measured by flicker or brightness minimization method.



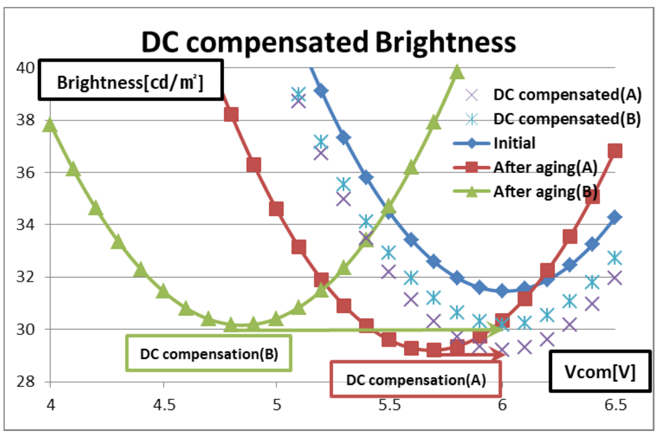
Graph 4. Optimal Vcom measurement by flicker minimization method

From the measurement of flicker Vs. Vcom voltage relationship, the Optimal Vcom voltage at each gray can be decided.



Graph 5. Movement of optimum Vcom voltage depending on aging condition. Aging time 60Hrs.

Graph 5 shows how much ΔR-DC changed by the different aging condition. Aging 0 gray(at area (A)) changes R-DC 300mV, while 255gray(at area (B)) changes 1110mV.



Graph 6. Movement of the Optimal Vcom voltage depending on aging condition.

Then Vcom - transmittance dependency was calculated when ΔR-DC is zero. If shift these Vcom-transmittance curve to each ΔR-DC value respectively, then the effect of ΔR-DC can be vanished.

Initial brightness	DC compensated brightness after aging	
Both (A) and(B) area	(A) area	(B) area
31.5	29.2	30.2

Table 1. Brightness of initial and after aging when DC image sticking components are eliminated.

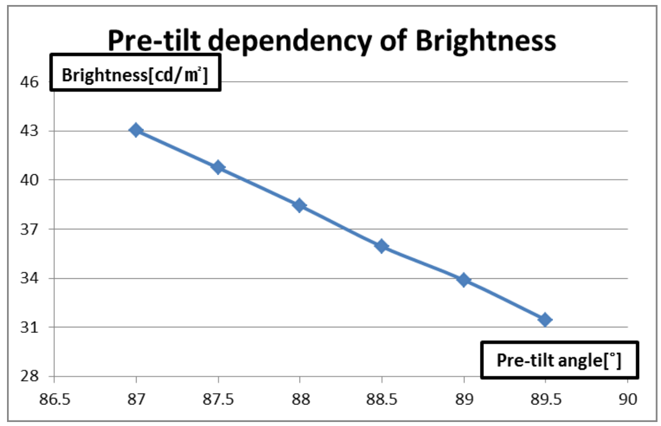
We can calculate the brightness at 128 gray when DC image sticking contribution is completely removed. This DC image sticking could be generated by 1) internal field due to ion impurities in LC and PI layer[7], 2) temporary polarity relaxation mismatching of a multi-layer stack of dielectric layers(LC/PI/LC)[8], etc.

6. AC Image sticking due to ΔPretilt

Graph 6 shows that brightness after aging without DC image sticking. The major causes of AC image sticking are ΔPretilt and ΔVHR. First, we would like to separate out the effect of image sticking by Pretilt angle change.

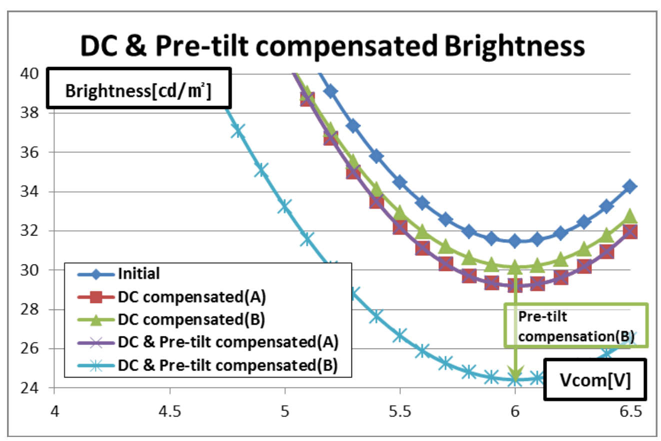
Test cells, as well as real panels, were used to measure the Pretilt angle of LC at alignment layer. The test cell was designed to measure electrical and optical characteristics easier because it has no TFT. It has already known that the Pretilt angle measurement result of the test-cell match with that of real-panel.

From the test-cell measurement results, Pretilt angle of each area is changed (A)89.5→89.5˚and (B)89.5→87.9˚ respectively. It means that only Pretilt angle at (B) area changed after aging period.



Graph 7. Pretilt angle dependency of brightness at 128 gray.

From graph of 7, when Pretilt angle change from 89.5 ˚ to 87.9˚ (by aging), then the brightness will 23.5% brighter at 128 gray. Then it could be calculated each area's brightness without image sticking due to DC and Pretilt angle causes by compensating brightness of 23.5%.

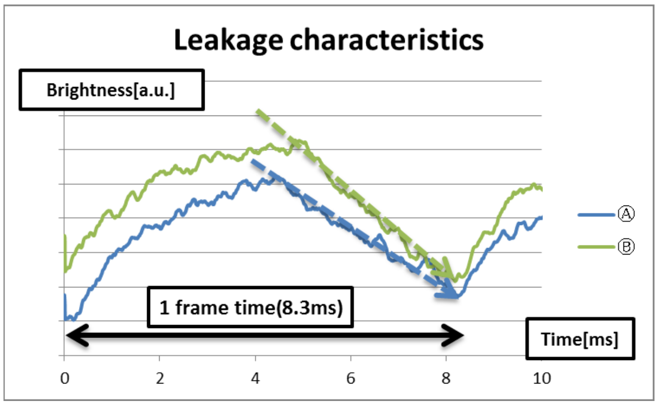


Graph 8. Transmittance dependency of Vcom voltage before and after aging. ΔR-DC and ΔPretilt angle effects are compensated.

7. AC Image sticking due to ΔVHR

When VHR is low, charges accumulated in the storage and LC capacitor would be dissipated rapidly. If so, the effective voltage applied to the cell will be decreased. VHR of a panel may be decreased by various reasons, just like increment of a number of ionic impurities or leakage current of TFT, and so on.

To know whether image sticking due to ΔVHR exist or not, the real time brightness measurement during a frame time could be a solution. Because direct measurement of the voltage level of the pixel electrode of TFT-LCD is very difficult, real-time optical measurement of brightness gives us information about VHR of TFT-LCD[9]. From this measurement, we could know that 1) there are different of leakages between (A) and (B) areas, 2) voltage drop at (A) area is faster than (B).



Graph 9. Comparison of leakage characteristics by optically measured at (A) and (B) area.

If causes of image sticking due to DC and Pretilt angle change can be compensated, there would only exist image sticking due to VHR. Therefore, it can be said that the difference between initial brightness and DC/Pretilt compensated brightness is image sticking phenomenon due to VHR.

	(A) area	(B) area
Initial	31.5	
After aging	30.3	44.4
DC compensated	29.2	30.2
DC & Pretilt compensated	29.2	24.4
DC & Pretilt & VHR compensated	31.5	

Table 2. Brightness change due to each image sticking causes at 128 gray.

8. Conclusion

Using this analysis method, we could calculate how much ΔR-DC, ΔPretilt, and ΔVHR contribute to image sticking as shown in Table 3.

	DC	Pretilt	VHR	Total
(A) area	1.1	0.0	-2.3	1.2
(B) area	14.2	5.8	-7.1	12.9

Table 3. Brightness contribution due to each image sticking causes at 128 gray.

9. Impact of This Research

To know how much these three key causes raise image sticking will be helpful to understand and decrease this phenomenon. But unfortunately, considering the allowed length of this paper, we did not explain about actual causes and improvement methods.

10. Acknowledgements

1) Data of this paper is measured just by using test product only.

2) Thanks to Hiroyuki Kamiya(FPD Solutions Co. Ltd) who give many pieces of advice on this research.

11. References

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