Mechanisms of Lens Mura and the improvement by increasing the width of share TFT

Wuguang Liu[1], Sheng Sun[1], Zhixiong Jiang[1], Meng Chen[1], Jubin Li[1], Woosung Son[1]

liuwuguang@tcl.com

[1] TCL China Star Optoelectronics Technology Co., Ltd, Guangdong, China, 518132

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ABSTRACT

The Lens Mura's production mechanism was analyzed in detail, and an effective improvement method with low cost and strong practicability in the G8.5 TFT LCD production line was proposed. We increased HT thickness and lengthened ash time, the width of share TFT's channel was increased, lens mura was less sensitive to process fluctuations, finally lens mura was improved.

1 INTRODUCTION

For the display industry, the exposure machine is indispensable. At present, the display industry generally adopts Nikon exposure machine, because it has high exposure accuracy and can be used for large panel size. But its optical system adopts a combination of multiple prisms for exposure, it is easy to generate lens mura, which has a greater impact on the panel quality. As shown in Fig.1, it is a common 55-inch LCD panel produced in G8.5 production line with 6 horizontal lens mura. At present, many manufacturers use the demura method to remove the lens mura, but the cost is relatively high. Some research team improved lens mura by changing the photoresist(PR) material, but it's hard to apply in the production line[1]. Therefore, how to improve lens mura from the process and design is an important research content in the current panel industry.

The generation of lens mura is due to the different exposure of the lens overlapped part and the non-overlapped part. The difference exposure caused by the Nikon exposure machine, which leads to the difference in some critical value of the TFT device, thus causes the different voltage of the lens overlapped part and the non-overlapped part of the panel. Finally there appears different brightness in display panel, which shows the lens mura.

This paper analysis how lens mura generated in detail and then provides a method to improve lens mura through process optimization.

2 ANALYSIS

Photolithography in the TFT-LCD manufacturing industry is a precision microfabrication technology in the semiconductor manufacturing industry. Exposure is an important and critical process in the photolithography process. The exposure process affects the accuracy of the graphics on the film[2].

2.1 Analysis of the Nikon exposure machine and the lens mura's origin

As shown in Fig. 2, the exposure is a structure in which the pattern on the mask is transferred to the glass substrate (Plate). The main structure of the exposure machine includes: Light source system (Lamp), Mask stage, Lens Module, Plate stage, Mask loader, Plate loader. The light in the Nikon exposure machine is projected downward through the prism combination system, 11 prisms form 11 beams, and the mask pattern is transferred to the substrate through 2 scans. Since the exposure system is a combination prisms, the edges of the two connected prisms are triangular, and the two triangles are connected to correct and compensate the light in order to achieve large-area exposure. However, there is still a certain difference in the focusing depth of the light between the lens overlapped part and the lens non-overlapped part of the prism, so there will be a certain difference in the exposure of the two parts during the exposure process. As a result, the TFT's Ch-W&Ch-L(channel width and channel length) of the lens overlapped part and the lens non-overlapped part transferred to the substrate is different(our several experiments on the 55-inch panel show that the W of TFT is 0.4um smaller in the lens overlapped part than in the non-overlapped part, and L is 0.2um larger), and the difference in the W&L of the TFT will directly lead to the difference in its electrical characteristics.

When the entire panel is lighted, the voltage of the lens overlapped part and the non-overlapped part changes, the voltage controls the deflection of the liquid crystal, and affects the transmittance of the backlight, that is, the final display's brightness of the lens overlapped part and non-overlapped part is different, so the lens mura appeared, the formation process is shown in Fig. 3.

2.2 Analysis of electrical differences in lens mura formation

After a large amount of data investigation and analysis, we found that the lens mura panels are all designed with 8-domain, while for the panels designed with 4-domain, lens mura does not appear. We will analyze the differences as follows:

After comparative analysis, it is not difficult to find that 4-domain is a 1T design, and 8-domain is a 3T design. As shown in Fig. 4(a), 3T includes three TFTs: main, sub, and share TFT. Main TFT controls main pixel brightness, and sub TFT and share TFT control sub pixel brightness. Under the same Nikon machine exposure, both will have a difference between lens overlapped and non-overlapped part, but for the 4-domain design panel, the overlapped area channel's W&L changes, the Ion changes, but the voltage of pixel is basically unchanged (when the screen is judged in gray pattern, the data signal is in DC mode, the charging ratio is always better, it can charge the pixel full immediately); for the 8-domain design panel, the channel's W&L variation in the overlapped area is easily to cause the different of the resistance ratio of sub and share TFT , resulting in a change in the voltage divider ratio, and finally the brightness of sub pixel Varied.

The brightness difference of sub pixel leads to lens mura's process analysis in detail in the following:

The brightness of sub pixel is controlled by the voltage division ratio of sub TFT and share TFT, while the voltage division ratio of sub TFT and share TFT is decided by these two TFT's Ch-W&Ch-L. The equivalent circuit diagram and equivalent resistance diagram are shown in Fig. 4(b)&(c). Under normal circumstances, the L of the two TFTs is designed not much different, but the W of the sub TFT is much larger than the share TFT. Therefore, when the process fluctuations cause TFT's Ch-W&Ch-L variation, the ratio of sub TFT's Ch-L to share TFT's Ch-L does not change much, but the ratio of sub TFT's Ch-W to share TFT's Ch-W varies greatly. From the analysis of the exposure process, it can be seen that the TFT's Ch-W&Ch-L values of the lens overlapped part will vary due to the difference in exposure, as the ratio of sub W and share W varied, the voltage division ratio of sub and share TFT will change, resulting in sub pixel brightness change, lens mura appears.

When the panel is lighted, the sub voltage can be expressed by the following formula:

$$V_{sub} = V_{data} - \frac{R_1}{R_1 + R_2} \cdot (V_{data} - V_s)$$
$$= \frac{R_1}{R_1+R_2} \cdot V_{data} + \frac{R_1}{R_1+R_2} \cdot V_s \quad (1)$$

As we known that, the current of TFT can be expressed by the following formula[2]:

When $V_{gs} > V_{th}$, $V_{ds} < V_{gs} - V_{th}$,

$$\mathrm{I} = \mu \cdot C_{OX} \cdot \frac{W}{L}(V_{gs} - V_{th} - \frac{1}{2}V_{ds})V_{ds} \quad (2)$$

When $V_{gs} > V_{th}, V_{ds} > V_{gs} - V_{th}$,

$$\mathrm{I} = \frac{1}{2}\mu \cdot C_{OX} \cdot \frac{W}{L}(V_{gs} - V_{th})^2 \quad (3)$$

from formula(2)&(3), it's easy to know that I is proportional to W/L, as we known R=U/I, thus the resistance ratio can be expressed by the following formula:

$$\frac{R_1}{R_2} \propto \frac{\frac{L_1}{W_1}}{\frac{L_2}{W_2}} = \frac{W_2}{W_1} \quad (4)$$

Since the channel length difference is small, the resistance ratio is equivalent to the channel width ratio(the resistance is inversely proportional to channel width). The change of the channel width ratio will directly affect the resistance divider ratio. Therefore, if we can reduce the change in the voltage divider ratio between sub and share TFT (W&L variation caused by exposure difference), we can improve lens mura.

3 EXPERIMENT

Our way to improve lens mura is to increase the width of share TFT's channel(simply called W). For a 3T structure to realize an 8-domain panel, the main and sub TFTs are usually designed to be U-shaped, and share TFTs are designed to be I-shaped. The channel length of the three TFTs are almost the same, but the W of U TFT and I TFT are very different, so increasing share TFT's W can directly reduce the variation of the ratio of sub W and share W. For LCD production lines, without changing the mask design and minimal process changes, increasing the W of the share TFT is the simplest and most effective method with the lowest cost to improve lens mura.

3.1 Experimental process

By increasing the thickness of half-tone(HT), the width of share TFT(3T-W) can be increased. The process of increasing 3T-W will be described below.

The process in this paper is implemented on the G8.5 production line, using the 4Mask process. The detailed 4Mask process can be checked in our previous patent[3]. This paper focuses on the analysis of the three key processes (Photo, 1st Wet, 1st Dry) to achieve 3T-W increase. We will analyze the three positions affected by the increase in HT, as shown in Fig. 5(a), the three positions are: (i) data line; (ii) W of share TFT; (iii) L of share TFT.

First of all is the process of Photo, by reducing the amount of exposure dose, the thickness and width of PR will increase compared to reference condition(REF). At this time, affected by the increase in PR thickness, (i)&(ii)&(iii) three positions changes are shown in Fig. 5(b): compared to REF condition, the thickness and width of the PR at the data line have a certain increase; the thickness and width of the PR in the W direction at share TFT have a certain increase; and so is the thickness and width has a certain increase of the PR in the L direction at share TFT, the CL becomes smaller than REF, at the same time, HT becomes thicker.

Then is the 1st Wet process, this process is mainly to etch away the metal which is not covered by PR. As shown in Fig. 5(c), as PR is thicker and wider than REF, the covered metal area is wider. Therefore, after the 1st Wet etching is completed, the metal width at the data line is increased compared with REF, and the metal at share TFT's L direction also becomes wider due to the wider PR.

Next is the 1st Dry process, which is mainly to etch away the PR in the TFT channel and open the channel. The key step is photoresist ashing(simply called ash). Since HT is thicker than REF, the ash time needs to be lengthened in order to open the channel, and also to keep the final data line width and channel length(CL) unchanged. As shown in Fig. 5(d), after the 1st Dry etching is completed, due to the lengthening of the ash time, the residual PR width at the data line remains consistent with REF, the channel of share TFT is opened, and CL remains consistent with REF. At this time, the only changes is 3T-W, since the previous width is wider than REF, at this time, the PR at the channel is completely dried away, and 3T-W is significantly larger than REF. In this way, increasing 3T-W is achieved.

4 RESULTS AND DISCUSSION

4.1 The result of G8.5 55-inch Panel W&L

We completed the process in the G8.5 production line and measured critical values by NAN and CDO machines. The results are shown in table 1: after photo, HT increased to 5776Å, which is 736Å larger than REF (5046Å), the data line width is 0.2um wider than REF, 3T-W is 0.2um wider than REF, and 3T CL is 0.2um smaller than REF, which is consistent with the previously analysis. After lengthen ash time to a certain value(the increased ash time will be certain fluctuations depending on the condition of the Dry machine), we got the AEI(After Etch Inspection) value consistent with expectations: data line width and TFT Ch-L are basically the same with REF, 3T-W has a significant increase, 3T-W is 6.43um, increases by 0.5um, compared with REF (5.93um).

4.2 Voltage simulation results and discussion

From lens mura formation process diagram(see Fig. 3), it can be seen that the difference in the brightness of the panel in the lens overlapped and non-overlapped parts is due to the difference in the voltage that controls the deflection of the liquid crystal, so if we can know the pixel's cross voltage, we can know the brightness of the pixel. In the following, we use the actual W&L value of the TFT in the lens overlapped and the non-overlapped parts to simulate the voltage of the pixel, the voltage indirectly indicates the lens mura condition. The relevant calculation formula is derived as follows.

The brightness difference between lens overlap and non-overlap:

$$\Delta Lv = Lv_{Lens\ OVL} - Lv_{Lens\ non-OVL} \quad (5)$$

As the display brightness is determined by the cross voltage loaded on the pixel(that controls the deflection of the liquid crystal), the relationship between the two can be represented by V-T curve, so the brightness difference can be indirectly represented by the voltage difference. For lens overlapped and non-overlapped areas, the pixel voltage(V_{pix}) can be expressed as follow:

$$V_{pix} = \sqrt{(V^+ - V_{Com})^2 + (V^- - V_{Com})^2} \approx V^+ - V^- \quad (6)$$

V^+ is the positive frame voltage, V^- is the negative frame voltage, V_{com} is the common line voltage. Voltage difference between lens overlap and non-overlap can be expressed as follow:

$$\Delta V = (V^+ - V^-)_{Lens\ OVL} - (V^+ - V^-)_{Lens\ non-OVL} \quad (7)$$

We use actual W&L value to simulate the pixel's voltage. (W&L of non-overlap is the experimental actual value, and L is actual value calculated from n+ to n+; W&L of overlap is the result value of complement from non-overlap's value, W complement is -0.4um, L complement is 0.2um), respectively simulate main & sub pixel voltage under the condition of L128&L255, the holding voltage value obtained as shown in table 2: REF condition, the voltage difference between Non-overlap and overlap is 0.1567V@L255, 0.049V@L128; HT increase condition, the voltage difference between non-overlap and overlap is 0.143V@L255, 0.047V@L128.

The voltage simulation results show that: 3T-W increases by 0.53um, the voltage difference decreases by 8.7% (that is, lens mura improves by 8.7%).

4.3 Actual brightness improvement result and discussion

We judge the panel's quality through JND(Just Noticeable Difference), and the results show that: HT increases condition, the JND is 2.3@L128, decreases 0.1 compared with REF (JND 2.4@L128). The result is shown in Fig. 6.

5 CONCLUSIONS

This paper analyzes the generation of lens mura in detail and further through the improvement process to improve it. Increasing HT thickness and lengthening ash time, the width of share TFT' channel is increased by 0.5um, and finally lens mura JND is improved by 0.1.

This paper showed a way to improve lens mura, without changing the mask design. It does not increase the cost and can be applied in production line immediately. The analysis method and improve results are of great and far-reaching guiding significance in the G8.5 TFT LCD industry.

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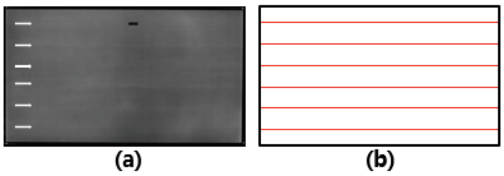

Fig. 1 G8.5 55-inch LCD 6 horizontal lens mura (a) physical image, (b) schematic diagram

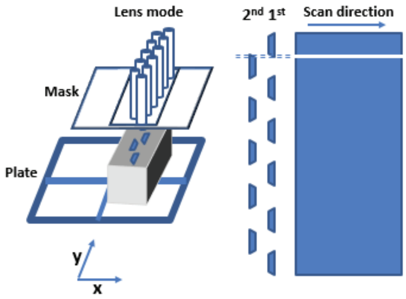

Fig. 2 Nikon Lens Modules

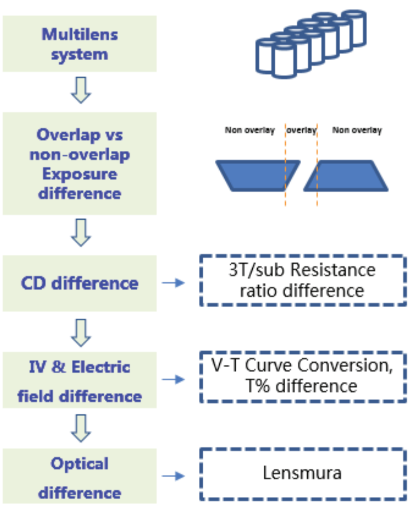

Fig. 3 Lens mura formation mechanism

Table 1 G8.5 55-inch Panel's W&L

Condition.	AEI-CD(um)			
	Data	3T Ch-W	3T Ch-L(M-M)	Main Ch-L(M-M)
REF	4.41	**5.93**	4.87	4.63
HT Increase	4.56	**6.43**	5.03	4.80

Table 2 G8.5 55-inch Panel voltage simulation results

Condition	Position	Main&Sub		3T		ΔV(Sub)	Mura
		W	CL	W	CL	@L255	@L255
REF	Non-overlap	21	3.81	5.85	4.05	0.1567	REF.
	Overlap	20.6	4.01	5.45	4.25		
HT Increase	Non-overlap	21	3.98	6.38	4.21	0.143	Improve 8.7%
	Overlap	20.6	4.18	5.98	4.41		

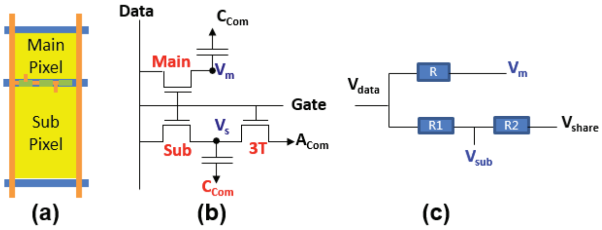

Fig. 4 (a) 8-Domain pixel design, (b) Equivalent circuit diagram, (c) Equivalent resistance diagram

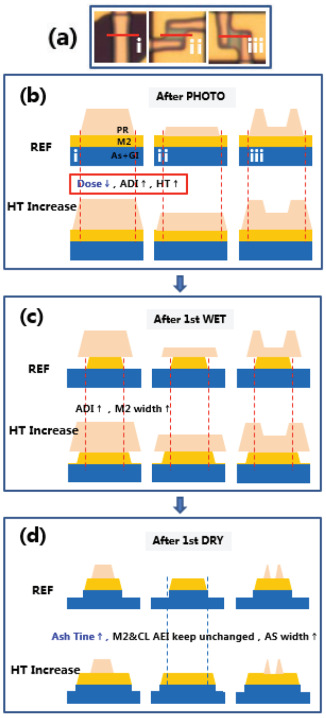

Fig. 5 (a)3 positions affected by HT, Changes of REF & HT increase (b)after Photo, (c)after 1st Wet, (d)after 1st Dry

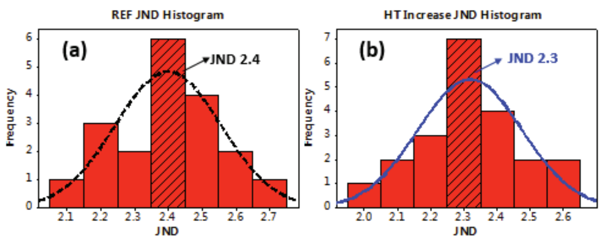

Fig. 6 (a)REF's JND Histogram, (b)HT Increase's JND Histogram