Research on Liquid-Crystal Phase Change Improvement of TFT-LCD TV Display

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Abstract

When the TFT-LCD TV products designed by GOA are tested for high temperature operation reliability, the liquid crystal phase change is easily caused by the leakage of TFT at high temperature. This paper deeply studies the cause of the liquid crystal phase change and plans a verification experiment, which greatly improves the occurrence of defects.

Author Keywords

Liquid crystal phase transition; Leakage current; TFT-LCD; GOA.

1. Introduction

With the development of TFT-LCD technology, narrow bezel displays have become the main trend in the development of high-quality displays due to their simplicity, aesthetics, and larger screen to body ratio. At the same time, in pursuit of lower production costs, GOA (Gate on Array) technology has emerged. GOA technology integrates the gate driving circuit of the display panel onto the array substrate to achieve a row by row scanning driving method for the gate. It can omit the external driving IC or COF on the gate side, which can reduce costs and is more conducive to narrow frame design. It has become the mainstream design method in the industry.

Due to the fact that GOA technology integrates gate driving circuits onto an array substrate, the integrated GOA driving circuit structure is complex, with a large number of TFT integrated circuits arranged, and TFTs are affected by the array substrate process technology, the instability of TFT devices themselves, and the design itself. When TFT-LCD display screens operate in high temperature environments, there are frequent issues related to the heating of GOA driver circuits, such as liquid crystal phase transition and POL burns. These issues pose a risk of product failure for customers during use in hot regions such as summer and Africa, prompting LCD panel manufacturers to improve and enhance product reliability. This article combines the discovery of poor liquid crystal phase transition in the 32FHD TRD a-Si product produced by HKC, analyzes its causes in depth, and finds that liquid crystal phase transition is related to high-temperature leakage current. By adjusting the thickness or film quality of the gate insulation layer, active layer, and passivation layer, as well as adjusting the etching power of the TFT back channel, TFT leakage can be reduced, thereby enhancing the high-temperature reliability of the product.

2. Reasons for the Phase Transition of Liquid Crystal

2.1 Confirmation of Adverse Phenomena

The 32FHD TRD VA display screen designed by GOA is undergoing HTO (50 ℃ or 60 ℃, Operation); During the reliability test at 8h, it was OK at 50 ℃, but 12.80% (484pcs female, 62pcs NG) of liquid crystal phase transition defects appeared at 60 ℃. When restored to room temperature, the liquid crystal phase transition defects disappeared. By human observation, black clusters appear at the corners on both sides of the Source side, and normal images cannot be displayed, as shown in Fig.1(a) and Fig.1(b). Using an infrared thermometer to measure the temperature at the abnormal location, the highest temperature has reached 72 ℃. Statistically, it was found that the membrane sites were concentrated, and the NG locations were concentrated in the middle of the large plate, as shown in Fig.1(c).

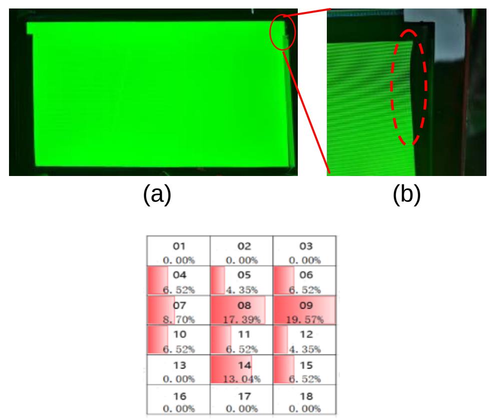

Figure 1. (a)32FHD Panel. (b)Liquid crystal phase transition on the Source side. (c)Distribution of Glass.

Table 1 shows the detailed results of HTO testing. With the progress of time, a certain proportion of liquid crystal phase transition appears. The proportion of liquid crystal phase transition increases first and then decreases with the aging time increasing.

Table 1. 32FHD HTO Results

HTO	Total	NG Panel in each stage/h							
		1	2	3	4	5	6	7	8
50°C	484	0	0	0	0	0	0	0	0
60°C	484	10	56	40	31	29	25	18	12

2.2 Analysis of Adverse Mechanisms

As shown in Table 2, we first analyzed the design frame of this product and investigated the comparison of similar products in the market. Competitor designed 32FHD products, mostly using non TRD designs, and our company uses TRD/GOA/Al process to design 32FHD, which has Cost Down and extremely strict requirements on the performance of TFT devices.

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Table 2. 32FHD Product Design Frame

Frame	GDL	Gate/SD (Al/Al)/ Å	C/L/ µm	S-COF/sh	
				Competitor	HKC
TRD	3240	4350/3800	4.1	6	2

The process structure of 32FHD consists gate, GI, I-a-Si, n^+a-Si, source and drain (S/D), and a passivation layer sequentially fabricated on a glass substrate, as shown in Fig.2. GI coating adopts CVD process, with three film formation speeds from bottom to top, namely high-speed(GH)、medium-speed(GM) and low-speed(GL) film formation. and the I-a-Si layer is also formed in low-speed(AL) and high-speed(AH) film formation. Both GI and I-a-Si have fast or low film formation, which is to consider reducing the production Tact time.

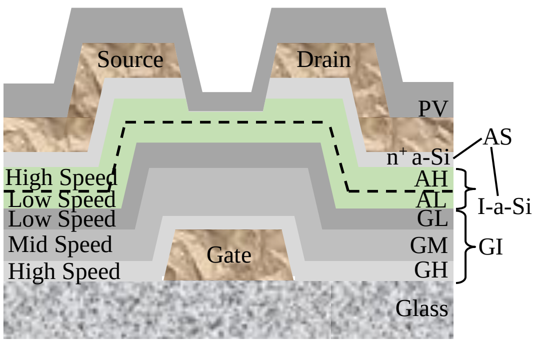
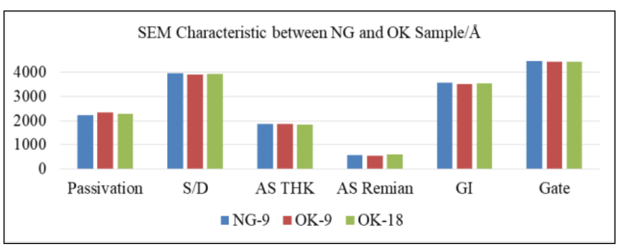
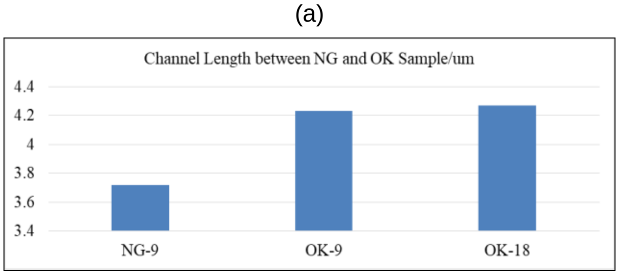


Figure 2. 32FHD Process Structure

we selected the high-frequency NG panel (Panel-9) and the same position (Panel-9) of OK panel, and the low-frequency panel (Panel-18) of the glass for SEM comparison, and compared the characteristic values of NG panel and OK panel. The NG panel showed no obvious difference, as shown in Fig.3(a). But it was found that Channel Length of NG sample was smaller than that of OK sample. as shown in Fig.3(b).



(a)



(b)

Figure 3. Comparison between NG and OK Sample. (a)SEM Characteristic. (b)Channel Length.

Then, TFT at the liquid crystal phase transition position of NG panel and OK panel was selected to test I/V curve at high temperature Stress(Vg=40V, Vd=10V, 60℃). It was found that at T0/1000s/4000s, I0(Vg=0V) of NG panel was lower than that of OK panel, and IV Shift of NG panel was larger than that of OK panel. Therefore, we determined that the TFT of OK panel was more stable than that of NG panel at high temperature. When a-Si: H TFT is aging, the carriers of NG TFT are more easily excited, resulting in an increase in leakage current. In addition, the initial TFT leakage is relatively large, and with the Aging at high temperature, the leakage gradually decreases, because the carriers in the TFT tend to be stable, as shown in Fig.4.

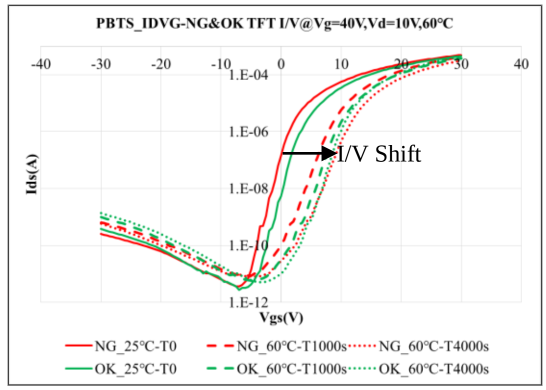


Figure 4. Comparison of I/V curves between NG and OK Sample

Based on the above analysis of the defect, we have determined that the direct cause of the defect is the high temperature in the GOA area, exceeding the clear point of the liquid crystal, resulting in liquid crystal failure and display defects. The root cause is that when the product is used for high-temperature, the TFT leakage is high and the current is too large, causing heating in the GOA area. The influencing factors of liquid crystal phase transition include GOA order, TRD and Al/Al process design, Channel Length. Excluding congenital design reasons, we will start with reducing the I(0) of TFT for improvement verification.

3. Improvement verification and result analysis

In summary, the direct cause of poor liquid crystal phase transition in TFT-LCD TV displays is the heating of the GOA circuit in high temperature environments. The temperature in the GOA area is too high, to exceed the clear point of the liquid crystal, resulting in liquid crystal failure and exhibiting liquid crystal phase transition; The fundamental reason for the heating in the GOA area is related to the high-temperature leakage current of the TFT in a high-temperature environment, where the high-temperature leakage current is large and causes heating. Therefore, we can improve liquid crystal phase transition by enhancing TFT stability and reducing TFT leakage current [1].

We have developed an experiment for this, and the experimental samples are made using the Chongqing HKC G8.6 Al/Al process technology to produce 32FHD TRD a-Si products. First of all, according to the analysis results of SEM characteristic, we increased the channel length of product to the level of OK panel, but there was no significant improvement, indicating that we still need to improve the product margin from other aspects.

Improve the experimental conditions as shown in Table 3. The experimental conditions were carried out by adjusting the thickness or film quality of the TFT gate insulation (GI), active and passivation layer, as well as adjusting the dry etching power of the TFT back channel. Measure the I/V curves of each group of conditions, extract I(0) characteristic values for comparison, and finally perform HTO projects on the samples to evaluate the improvement effect of each experimental condition on the poor liquid crystal phase transition of the product. To ensure accuracy, the number of HTO input for each condition is 72 panels, that is, 4 full panel of glass.

Table 3. Improvement of experimental conditions

Direction	Sample	Condition	I(0)	Ref.	HTO_60 °C/8h
STD	Split-STD	5/8kW, Pressure25mTorr	9.17 E-08	100%	9/72
GIN	Split-A1	GM+500 Å	3.18 E-08	34.70 %	6/72
	Split-A2	GL+500Å	3.06 E-08	33.40 %	5/72
AS	Split-B1	AH+500 Å	1.26 E-08	13.70 %	0/72
PV	Split-C1	PV+500Å	3.78 E-08	41.20 %	5/72
D/E	Split-D1	5/8.5kW, Pressure70mTorr	2.06 E-08	22.50 %	3/72
Power	Split-D2	4/6.5kW, Pressure50mTorr	1.20 E-08	13.10 %	0/72

From Table 3, it can be seen that Split-STD is the mass production control group, exhibiting a higher proportion of liquid crystal phase transition. In adjusting the thickness or film quality conditions of the gate insulation layer, Split-A1 increases the GM thickness by 500Å, while Split-A2 increases the GL thickness by 500Å. Both Split-A1 and Split-A2 can reduce I(0) and decrease the liquid crystal phase transition ratio. This is because increasing the thickness of the gate insulation layer or the thickness of the slow acting film layer can reduce capacitance and minimize leakage caused by GI layer defects on the front channel, thus reducing overall leakage current [2]. In adjusting the thickness conditions of the active layer, Split-B1 increases the AH thickness by 500Å, and the AS layer below the source and drain is equivalent to an upper and lower resistance. Increasing its thickness can increase the resistance, thus significantly reducing the leakage current and completely improving the liquid crystal phase transition ratio. In adjusting the passivation layer thickness conditions, Split-C1 can also reduce leakage by increasing the passivation layer thickness by 500 Å, as the passivation layer can protect the back channel and reduce the liquid crystal phase transition ratio. In adjusting the etching power conditions of TFT back channel, Split-D1 reduces the etching power and increases the pressure, while Split-D2 reduces the etching power and increases the pressure. Among them, Split-D2 can significantly reduce leakage and completely improve the liquid crystal phase transition ratio. This is because reducing power can minimize damage to the back channel [3].

According to the RA results, Split-B1, Split-D2 and STD conditions were selected for high-temperature stress I/V test. As shown in Fig.5, The results showed that the I(0) of Split-B1 and Split-D2 were lower at T0/T1000s/4000s, and the IV Shift of Split-D2 was less, the high temperature stability of TFT is better. Therefore, we chose the condition Split-D2 as the final improvement condition.

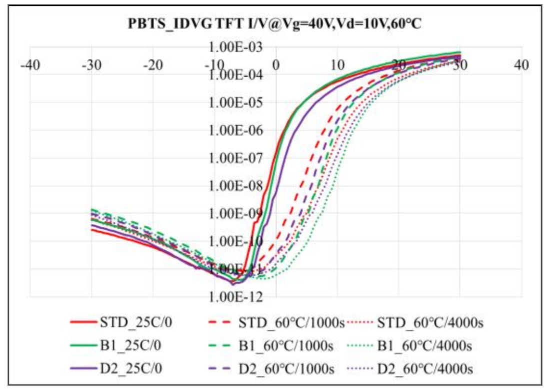


Figure 5. Comparison of I/V curves of Sample

Through the above scheme and experimental verification, it can be seen that by increasing the thickness of the TFT gate insulation layer, active layer, and passivation layer, adjusting the film quality, and reducing the etching power of the TFT back channel, the leakage current of the TFT can be effectively reduced, the heat generation in the GOA region can be reduced, and the occurrence of phase transition defects in the high mountain liquid crystal can be effectively reduced.

4. Conclusion

In this paper, the liquid crystal phase transition anomaly caused by TFT-LCD TV display working at high temperature environment is deeply analyzed and improved. Through electrical testing, it is confirmed that the direct cause of the bad occurrence is the heating of GOA circuit, which leads to the liquid crystal phase transition. By adjusting the thickness or film quality of TFT gate insulation layer, active layer and passivation layer, and adjusting the etching power of TFT back channel, the improvement direction is finally determined. It can provide reference for TV product analysis and improvement of liquid crystal phase transformation and TFT leakage under high temperature environment.

5. Acknowledgements

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6. References

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