P-112: A Novel LTPS Transflective TFT LCD Driving by Double Gamma Method

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Abstract

A novel method to realize the good performance of transflective LCD is indicated. In one pixel, two LTPS (Low-temperature poly-Si) TFT devices control the optical intensity of the transmissive and reflective regions respectively. We call this way as double gamma method (DGM). Uni-gap transflective LCD attached the DGM will have both merits of simplifying processes and good legibility. Meanwhile, we show the experimental results of optical characteristics with uni-gap homeotropic panel design. It obviously shows that high contrast ratio and wide viewing angle have been achieved.

1. Introduction

As the wireless communication technology expanding, the personal digital products such as cellular phone, personal digital assistant (PDA) have become the necessaries in daily lives. Among these numerous products, display panel plays an important role in message communication. Liquid crystal display (LCD) is adopted popularly in portable information products due to its features including low power consumption, light weight and thinness. But, the wash out of information is a serious drawback while using transmissive LCD (T-LCD) outdoors. Reflective LCD (R-LCD) seems to be more suitable than T-LCD due to its excellent legibility in outdoor use and extra low power consumption. Although R-LCD shows good performance in outdoor use, its brightness and color purity will drop drastically while using in dull ambiance. Therefore, R-LCD equipped with front light system has been developed to resolve the above-mentioned problems. After many engineers' efforts and evaluations, R-LCD equipped front light does not seem to satisfy the higher request of good legibility in use. Meanwhile, they think that it is complicated and difficult to design the front light system possessing good legibility on the panel. To sum up above descriptions, transflective LCD (TR-LCD) seems to become the unique solution to resolve all problems and possesses good performance in indoor or outdoor use.

In early design of uni-gap TR-LCD, one pixel is separated into transmissive and reflective regions in order to execute individual displaying functions. Because the optical path differences are different between transmissive and reflective regions, it does not achieve optimum optical efficiency in such design. In order to improve optical performance of TR-LCD, multi-gap design has been developed [1~4]. Multi-gap design possesses superior consistency of optical path difference between transmissive and reflective regions so that it achieves good legibility. Although the multi-gap design makes the superior optical performance, controlling an accurate gap thickness in manufacturing processes seems to relate the yield drop and cost increase. In order to simplify manufacturing processes and possess good legibility simultaneously, we indicate a novel method to realize a TR-LCD having excellent optical characteristics. In this paper, we will introduce the merits of TR-LCD with double gamma method (DGM). Meanwhile, we show experimental results of optical performance in our panel design.

2. Design concept

To design a good performance TR-LCD is always a challenge for panel designer. The challenge mainly originates the difficulty in the optimum optical consistencies of transmissive and reflective performance simultaneously. If we change the one TFT design to adopt two TFTs to drive the transmissive and reflective region respectively, we think that a good TR-LCD easily designed and manufactured will be achieved. A pixel of TR-LCD controlled with two TFTs will possibly meet some expected problems including yield decrease, cost increase and panel dimension enlarging etc. After we carefully analyze these questions mentioned above, we think it possesses potentialities to compete other modes while TR-LCD operating with DGM. The bases of our opinions are as follows: Firstly, the same design rule is adopted for two TFTs in order to achieve the same processes and keep the same cost as one TFT design. Uni-gap design on panel is more easily manufactured than multi-gap one, so that it will be contributive for yield rate. Secondly, both one and two TFTs panels have the same power consumption while operating in reflective mode. While operating in transmissive mode, the major power consumption is originated from back light system. It is far larger than the consumption of TFT devices. Therefore, we think that both one and two TFTs panels will have almost same power consumption and they are suitable for portable products. Thirdly, the quantities of driver ICs are the same as the ones for one TFT operating. In our design, one scan and two data lines are arranged in one pixel so that no scan driver ICs increase and data driver ICs also keep the same by switching. Although the data driver ICs must be double frequency, it is certainly achieved in present IC technology. Therefore, it is not necessary to add extra IC cost in our design. Due to two data lines use in one pixel, the connecting pad electrodes will be double so that panel dimension increases about 0.2mm on one side. Although the panel weight increases in our design, it is also acceptable because of the weight increase not so much while comparing with the weight of one TFT panel. Finally, in our design (4 inch QVGA TR-LCD), two TFTs are built under the reflector, so that the aperture ratio will be maximum usage in transmissive area. For LTPS processes, two TFTs built simultaneously under reflector is easy to approach in conditions of 4 inch QVGA panel. It is acceptable for all applications of portable products. In the future, it will possess more competitiveness if the driver ICs and functional circuits are integrated on panel. To sum up our opinions mentioned above, we decide to develop the TR-LCD with DGM. Figure1 shows the configuration of packaged panel in our design. Obviously, there is no difference while comparing the traditional panel except inside.

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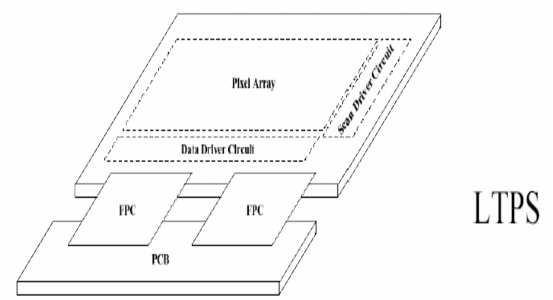

Figure 1 The configuration of packaged panel

Uni-gap TR-LCD with DGM is suitable for simplifying manufacturing processes and optimizing optical efficiency easily. It is not necessary to control accurate multi-gap thickness to satisfy the conditions of optical consistency between transmissive and reflective regions. Meanwhile, the optimum optical efficiency of transmittance and reflectance will be controlled easily in two TFTs use individually. Figure2 shows a side view of panel structure in our design. Each pixel is divided into reflective and transmisive areas, which electrodes (aluminum for reflective area and ITO for transmissive area) are connected to different drain terminals of two TFTs individually.

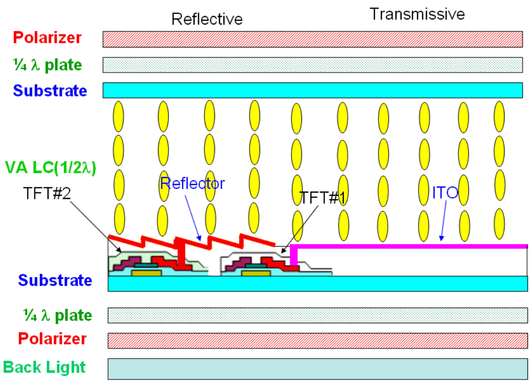

Figure 2 The structure of TR-LCD with double gamma method (DGM)

Therefore, transmissive and reflective regions are driven separately in order to get good optical efficiency. For increasing the aperture ratio of transmissive area, the TFT driving transmissive mode is also built under the reflector. The reflector is designed and fabricated with gray-tone exposure [5]. In our design, it does not increase extra steps during TFT manufacturing processes. Homeotropic aligned cell with negative dielectric anisotropy liquid crystals is adopted. In order to satisfy the normally black mode, a pair of quarter-wave plates are adopted in the front and rear side on the panel.

3. Experimental result

The simulation result of optical performance in our design has been published in IDMC03 [6]. In this paper we show the measured optical performance of designed cell. Cell gap is 3.8um. Figure3 shows the curve of transmittance vs. voltage. The threshold voltage is about 2.5 volts and saturation voltage is about 8 volts. Figure4 shows the experimental contrast ratio distribution in our design while the transmissive mode operating and no compensated film added. The maximum contrast ratio approaches 310 and the value can also approach 120 in normal directional view. As shown in Figure5a and Figure5b, the horizontal viewing angle (CR>10) can reach 120 degree and the vertical viewing angle (CR>10) can reach more than 160 degree with no compensation film. The viewing angle of this new design is wider than any other structures of transflective LCDs. The measurement of response time is about 21 msec.

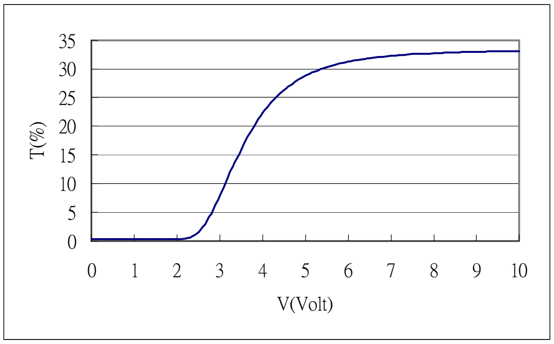

Figure 3 The curve of applying voltage vs. transmittance

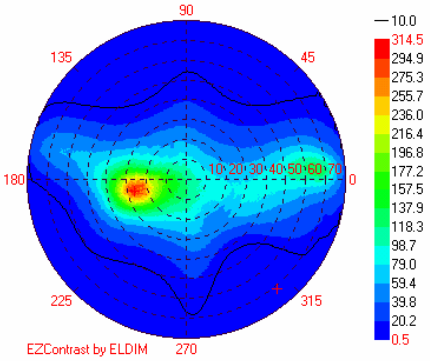

Figure 4 The contrast ratio distribution of the transmissive region while no compensation film use.

4. Conclusions

TR-LCD with DGM is a solution to get a good legibility performance. It possesses a potential to compete the other TR-LCDs. Any operating mode without complicated design and process can be arranged with DGM. In our homeotropic TR-LCD, high contrast ratio and wide viewing angle characteristics are achieved. By using two TFTs in one pixel, we can drive transmissive region and reflective region separately. Compared with traditional one-cell-gap and double-cell-gap transflective LCDs, this newly design can have higher transmissive optical efficiency and simplified processes. Two TFT devices control the optical performance of tranmissive and reflective regions respectively. In this way we can optimize the gamma curve and get the best light efficiency both in transmissive region and reflective region. Finally, we make a table (Table 1) to compare with the performance and manufacturing processes of present TR-LCD technology.

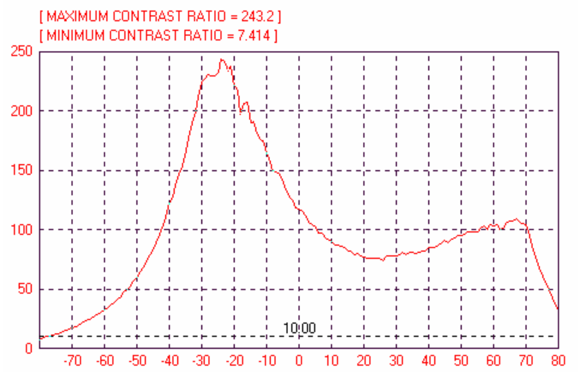

Figure 5a The horizontal characteristics of contrast ratio distribution in the transmissive region of experimental cell without compensation film

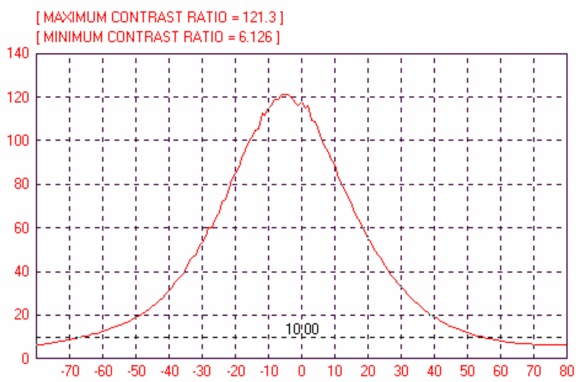

Figure 5b The vertical characteristics of contrast ratio distribution in the transmissive region of experimental cell without compensation film

5. Acknowledgements

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6. References

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Panel design	Performance	Manufacturing processes
1 TFT uni-gap	Not Good	Easy
1 TFT multi-gap	Good	Difficult
2 TFTs uni-gap	Good (Excellent)	Easy

Table 1 The comparisons for different TR-LCD technology