26-1: A Novel Transflective-type LTPS-LCD with Cap-Divided VA-Mode

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Abstract

A novel transflective-type LC mode with good display performance has been developed. In order to drive both transmissive and reflective modes simultaneously without any modulation of gamma in a single-gap structure, we have introduced a new design concept in the reflective region, where the capacitance is separated into liquid crystal(C_{LC}) and organic layer(C_{OL}), playing a key role as a voltage divider in our cap-divided VA-mode. With this cap-divided method having both merits of simplifying process and good legibility, we have achieved good optical characteristics such as high contrast ratio and wide viewing angle in a single-gap homeotropic panel design.

1. Introduction

As the mobile telecommunication technology is rapidly developing, a demand for portable displays with characteristics of wide viewing angle, good outdoor legibility and high color purity is growing fast. Among various types of display devices, LCDs are adopted popularly and widely in portable information products due to their features including low power consumption, light weight and compact size. The transmissive-type LCDs, however, have such an intrinsic problem as poor legibility under the sunlight, which is a serious obstacle for the optimum mobile display solution. Although the reflective-type LCDs seem to be more suitable than the transmissive-type LCDs in view of their excellent legibility in the outdoor use and extra low power consumption, they also have some drawback whose brightness and color purity will drop drastically while using in dull ambience. From the viewpoint which type of LCDs can satisfy better the above requirements in portable display devices, transflective-type LCDs seem to be the unique solution due to their outstanding performance in both indoor and outdoor use compared to transmissive-type and reflective-type LCDs.

In an early design of single-gap transflective-type LCDs, MTN(Mixed-mode Twisted Nematic)-mode[1~2] was generally used. However, because the optical path differences are different between transmissive and reflective regions in MTN-mode, it is quite difficult to achieve optimum optical efficiency in such design. In order to improve optical performance in the transflective-type LCDs, a multi-gap design has been proposed[3~4]. A multi-gap design possesses a superior consistency of optical path difference between transmissive and reflective regions so that it can achieve good legibility. Although a multi-gap design shows the superior optical performance, the strict requirement to control the cell gap accurately in manufacturing processes seems to result in the yield drop and cost increase. In order to simplify fabrication processes and achieve good legibility simultaneously, we have developed a novel single-gap design, named as a cap-divided VA(Vertical Alignment)-mode, an excellent alternative to overcome the disadvantage of a double gamma driving method in the former transflective VA-mode[5-8]. In this paper, we will elucidate the principle of our cap-divided VA-mode, especially making an emphasis on the simplicity in the driving mechanism due to its single gamma method. Meanwhile, the experimental verification will be done through confirming the optical performance in our cap-divided VA-mode panel design.

2. Panel Designing

In order to avoid the complexity of double-gamma driving method, where LC cell is driven selectively with two different gammas : one gamma is applied for transmissive-mode operation and the other is for reflective-mode operation, we have created a new design concept that both transmissive and reflective mode could be operated simultaneously with a single-gamma driving method, so called, a cap-divided VA-mode. As shown in Figure 1, in the reflective region of each pixel, the capacitance is separated into liquid crystal(C_{LC}) and organic layer(C_{OL}) by inserting such an additional dielectric medium(organic layer) between liquid crystal and indium tin oxide(ITO) in the upper substrate, while the capacitance(C_{LC}) in the transmissive region of each pixel is kept intact. Through this parallel connection of capacitor, the voltage applied to the liquid crystal in the reflective area of each pixel would be divided into two parts, V_{LC} and V_{OL}, according to the degree of each capacitance. Since the capacitance is dependent on the thickness of layer(d) and dielectric constant(ε), the amount of voltage needed for the liquid crystal in the reflective region to be half-switched can be adjusted with varying such parameters.

Figure 1 A equivalent circuit diagram of a pixel TFT

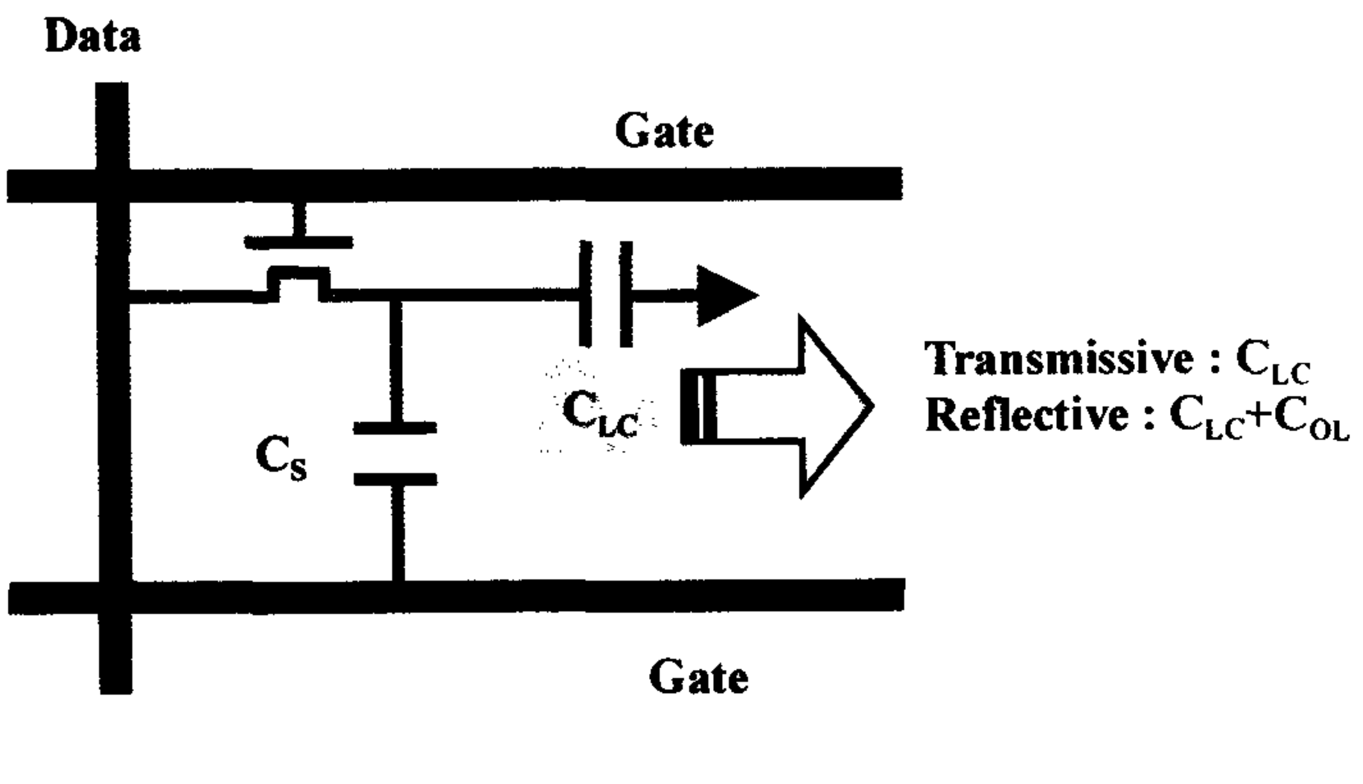

Figure 2 shows a cross sectional view of panel structure in our cap-divided VA-mode design. Each pixel is divided into reflective and transmissive area, the former is made of aluminum embossed on unevenly shaped acrylic resin, and the latter is made of indium tin oxide(ITO) for the transmission of light. In the reflective region, as shown in the figure, an organic layer is inserted between liquid crystal and ITO of the upper substrate. For the improvement of reflectance, we have also used a two-tone color filter, in which a light hole is made in the reflective region of each pixel(not explicitly drawn in the figure)[9]. The liquid crystal molecules with negative dielectric anisotropy are aligned perpendicular to both upper and lower substrates. In order to satisfy the operation of normally-black mode, a pair of quarter-wave plates(QWP) are placed on both the front and the rear side of the panel.

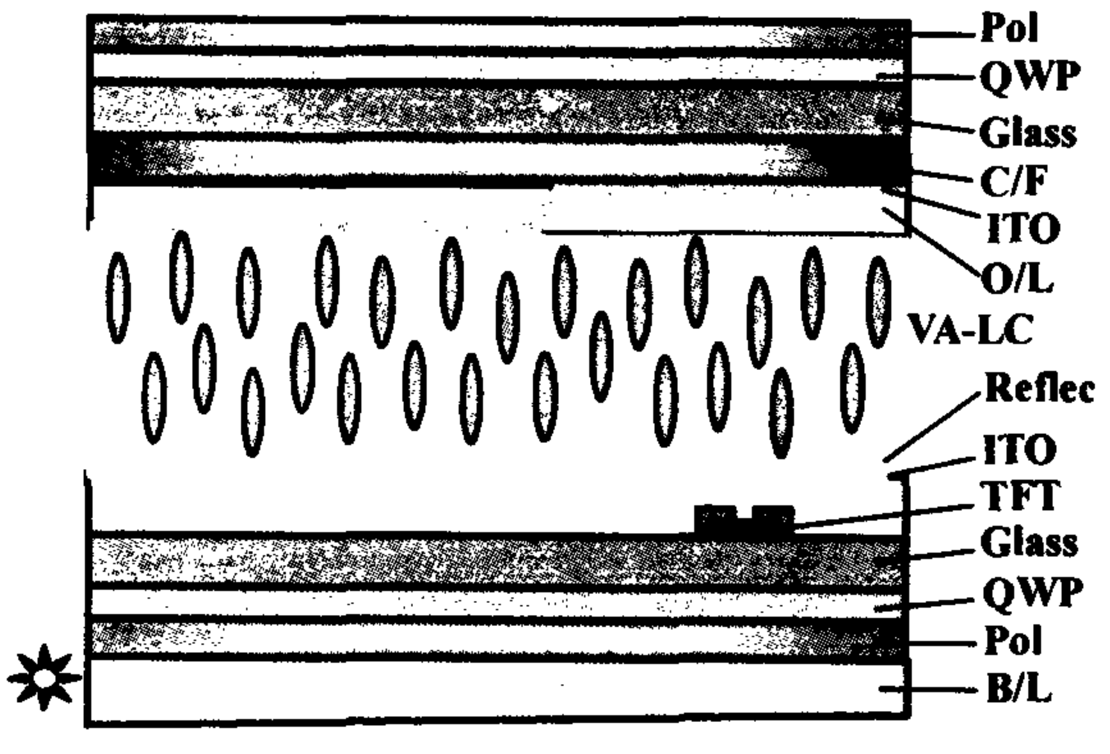

Figure 2 A panel structure of our cap-divided VA-mode LTPS-LCD

3. Experiment

3.1 Optimization of Capacitance

As mentioned previously, since the capacitance(C_{OL}) of organic layer is dependent on the thickness(d) of the layer and its dielectric constant(ε), the optimum capacitance value in our cap-divided VA-mode can be found through adjusting those parameters. For our convenience, we have selected a transparent dielectric material, a photo definable organic material, as our organic layer and varied its thickness from 1.0um to 1.6um with a step of 0.3um in order to find an optimum capacitance value, while the cell gap was kept to be about 3.8um.

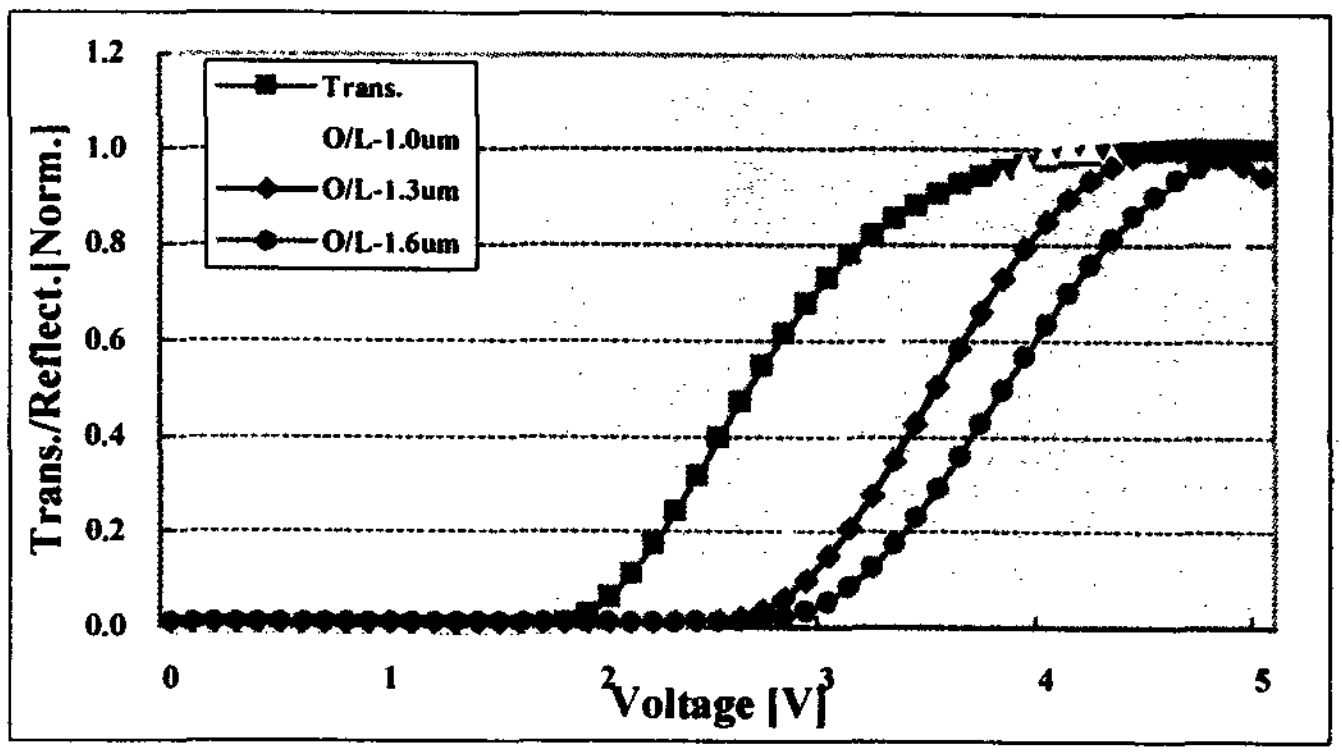

Figure 3 Measured V-T and V-R Curve of our cap-divided VA-mode, where O/L means the thickness of organic layer in the reflective region and Trans stands for a transmittance curve.

Figure 3 shows measured V-T and V-R curve with respect to varying thickness of organic layer in our cap-divided VA-mode LTPS-LCD, where both reflectance and transmittance are normalized for the convenience of gamma comparison between V-T and V-R curve. As can be seen from the figure, a gamma of V-R curve is shifted from left to right as the thickness of organic layer increases. Among three cases of V-R Curve, a gamma for the thickness 1.3um is well matched to that of V-T curve, which means the voltage sharing between liquid crystal and organic layer in the reflective mode operation is done appropriately in case of 1.3um thickness. The thinner the thickness of organic layer is, the more the gamma of V-R curve becomes close to that of original VA-mode, which needs to be driven with dual-gamma method in a single-gap structure.

3.2 Optical Performance

As shown in Table 1, we have achieved an excellent optical performance due to the characteristics of vertical alignment mode, where the reflectance was measured with optical system which the light source is illuminated obliquely with incidence angle of 30 degree and the reflected light is detected with a photo detector located perpendicular to the panel. The reflectance of our cap-divided VA-mode is about 5%. Contrast ratio in the transmissive mode reaches up to 300, which is 2 times higher than that of homogeneous alignment mode. Viewing angle is also much wider than the planar mode, almost 2 times wider in both vertical and horizontal direction, due to the nature of vertical alignment. Since we have used a color filter of 30% color reproducibility, the resulting color gamut in the transmissive mode turned out to be 28%.

Table 1. Optical performance of our cap-divided VA-mode

Item	Cap-divided VA-mode
1. Contrast	300
2. Viewing angle (CR>10)	Horizontal : >160° Vertical : >140°
3. Color Gamut	28%
4. Response time	23 ms
5. Reflectance	~5%

4. Conclusions

We have developed a novel transflective color LTPS-LCD with cap-divided VA-mode that has superior optical performance such as higher contrast ratio and wider viewing angle due to the characteristics of vertical alignment. With adopting a new design concept to divide the capacitance in the reflective region of each pixel, we have achieved a simple driving scheme of single gamma through matching V-T and V-R curve. By adjusting the thickness of organic layer inserted between liquid crystal and ITO, we have optimized the capacitance of its dielectric medium to show the similar gamma between V-T and V-R curve. Compared with conventional double-cell gap transflective LCD using homogeneous alignment mode or a single-cell gap transflective VA-LCD using double gamma driving method, this new design can have higher transmissive optical efficiency and simplified processes. We believe this new transflective color LTPS-LCD with cap-divided VA-mode has higher potential for high end markets of mobile applications like PDA, Cellular phone, and DSC.

5. References

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