

## Development of the advanced transfective LCDs with high optical performance

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### Abstract

*We have newly developed transfective LCDs with a specific sub-pixel and the single cell gap structure. In our structure, the overall transmittance and reflectance has become higher than typical transfective LCDs. Furthermore, it can simplify the fabrication process of the transfective LCDs.*

### 1. Introduction

Transflective liquid crystal displays(LCDs) have a lot of advantages for portable displays due to good outdoor visibility and low power consumption[1]. Pixels of transfective LCDs are normally divided into the transmissive and reflective regions. The light generated from the backlight is transmitted through the transmissive part and the ambient light is reflected on the reflective part. For this reason, the difference of the optical phase retardation of the light between two parts can occur. The typical compensation method of this difference is to apply the different cell gap configuration to each part[2].

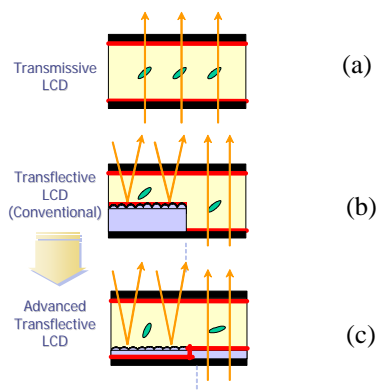
However, although the dual-gap panel shows the excellent compensation of the optical path difference, it has several intrinsic problems. It has low transmittance since the size of transmissive part is quite small compared to the transmissive LCDs, which can cause bad indoor visibility and high power consumption. Furthermore, the fabrication process of the dual gap is so complicated that the yield of production is not high. Thus, several single cell gap structures of transfective LCDs have been suggested in early studies. But it is quite difficult to attain the optimal condition of optical characteristics of the transmissive part and the reflective part, and the complexity of the driving method and the pixel design can not be easily avoided as well.

Here, in order to overcome such drawbacks as lower transmittance, the insufficient efficiency of reflectance, the complication of the fabrication process and the driving method, we have proposed the novel design of the single cell gap structure with adopting an insulation layer and an additional white sub-pixel.

Through this structure, we can achieve outstanding optical performances and the simple fabrication process simultaneously.

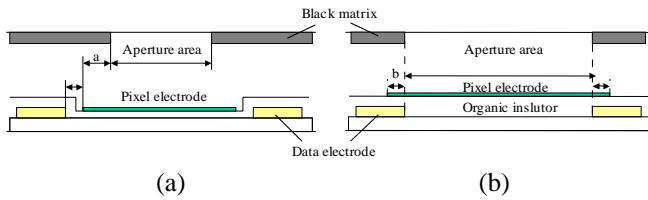
### 2. Design principle of single cell gap

As previously described, transfective LCDs have intrinsically the difference of the optical phase retardation between the transmissive part and the reflective part. Due to this optical phase retardation difference, it is necessary to apply different operation voltages to each transmissive and reflective part in the single cell gap structure.



**Fig. 1. (a) transfective LCDs (b) conventional transfective LCDs and (c) single cell gap transfective LCDs**

As shown in the Fig.1.(c), the pixel electrode of reflective part is formed under the layer of the low dielectric insulator and electrically connected to the pixel electrode of transmissive part. Since the low dielectric insulation layer acts as the voltage divider, the pixel voltage of the reflective part is reduced according to the electrical characteristics of the insulator. Additionally the specific shape of the pixel electrode of the reflective part is formed and controlling the size of the reflective pixel electrode and the characteristic of insulation layer, the optical phase retardation of the light propagating through the reflective region can be consistent with that of the light propagating through the transmissive region. Accordingly two parts can be operated by the single gamma driving.



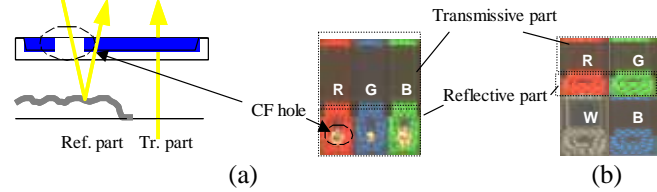
**Fig. 2. Transmissive part of (a) conventional transfective LCDs and (b) single cell gap transfective LCDs**

As shown in Fig.2., the low dielectric insulator layer, which is formed between the pixel and the data electrode, reduces the capacitance coupling between two electrodes. The pixel electrode can overlap the data electrode unlike the transmissive part of the conventional dual gap transfective LCDs, thereby enlarging the transmissive area. In addition, the black matrix to shield the light leakage can be eliminated so that the efficiency of transmission as well as that of reflection can be enhanced.

### 3. RGBW Quad pixel structure

The ambient light passes through color layers twice in the reflective region. Thus, the color of the reflective light is overly saturated resulting in the color difference between the reflective region and the transmissive region, so the efficiency of reflection is basically low. In the reflective part of conventional transfective LCDs with RGB sub-pixel, hole patterns are formed in the middle of color layers in the reflective region as shown in Fig. 3.(a). The ambient light passes through these holes without experiencing color layers and reflects on the reflecting surface,

which can enhance the reflectance and match the color saturation.



**Fig. 3. (a) conventional RGB stripe sub pixel and (b) new RGBW sub pixel**

In this work, we have applied the quad pixel structure which comprised of four RGBW sub pixels in color layers[4]. With adopting the white sub pixel, the hole pattern can be eliminated because the white sub pixel can substitute for the role of the hole pattern. Due to the white balance of the reflecting light, the size of the hole pattern of each color is limited. Therefore, the area of the substituted white sub pixel will be larger than that of the hole pattern. With adjusting the white sub pixel driving, we can control the reflectance within some range as we need. The white pixel can increase the overall panel transmittance at the same time

Comparing to the conventional transfective LCDs, the increase ratio of the transmittance and reflectance of the advanced transfective LCDs can be expressed as follows respectively.

$$\frac{T_{W+}}{T_{RGB}} = \frac{AR_{W+}}{AR_{RGB}} \times \left( 0.75 + 0.25 \times \frac{T_W}{T_{CF\_T}} \right) \quad --(1)$$

$$\frac{R_{W+}}{R_{RGB}} = \frac{AR_{W+}}{AR_{RGB}} \times \left( 0.75 \frac{T_{CF\_T}^2}{T_{CF\_R}^2} + 0.25 \times \frac{T_W^2}{T_{CF\_R}^2} \right) \quad --(2)$$

(1 line spacing)

Where T is transmittance,  $T^2$  is transmittance of the color filter twice and AR is the aperture ratio of the pixel.

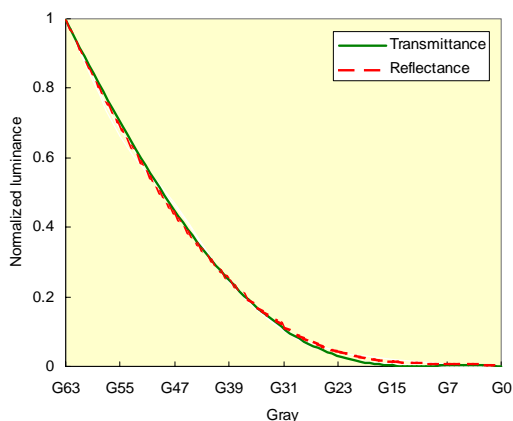
$$\frac{T_{W+}}{T_{RGB}} = 1.35 \frac{AR_{W+}}{AR_{RGB}} \quad --(3)$$

$$\frac{R_{W+}}{R_{RGB}} = K \frac{AR_{W+}}{AR_{RGB}} \quad --(4)$$

We have obtained the equation (3), (4) by plugging the experimental values in the equation (1), (2) respectively. From the equation (3), the transmittance of the advanced transfective LCDs become higher up to 1.35 times than the conventional transfective LCDs. In the equation (4), the constant K can be varied from 0.9 to 1.18 depending on the size of the hole pattern in RGB color filters.

#### 4. Electro-optical characteristics

We have successfully developed the transfective 12.1" WXGA(1280×800) TFT-LCD with the single cell gap structure and the RGBW quad pixel system.



**Fig. 4. Gamma curves of the transmissive and reflective part.**

The Fig.4. shows that gamma properties of the reflective part have been substantially the same as gamma properties of the transmitting part. This result indicates that the reflective region is operated properly by the single gamma.

**TABLE 1. Optical characteristics of various types of LCDs**

		Conventional transmissive LCDs	Conventional transfective LCDs	Advanced transfective LCDs
T	Luminance	200nit	150nit	200nit
	Color Gamut	45%	35%	45%
	Viewing Angle	50 ° /90 °	130 ° /130 °	160 ° /160 °
R	Contrast Ratio	-	10:1	15:1
	Color Gamut	-	10%	~20%

The optical characteristics of various types of LCDs are listed in Table 1. above. In particular, the advanced transfective LCDs has as the same luminance as that of the conventional transmissive LCDs even though dimension of RGB sub-pixel is decreased to 0.75 of that of RGB stripe type.

#### 5. Conclusions

The advanced transfective LCDs with high transmittance and the efficiency of the reflectance have been achieved with the RGBW quad pixel system and the single cell gap structure. In addition, the single gamma driving has been successfully realized resulting in the higher yield of mass production.

#### 6. References

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