High-Transmissive Advanced TFT LCD Technology

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Abstract

We have developed a novel TFT-LCD that is named as High transmissive advanced TFT-LCD for mobile use. This LCD has a novel and quite different structure compare to the conventional transflective LCD. We have achieved the same display quality as the transmissive LCD for indoor use, and at the same time achieved the good visibility under the sun light.
We describe the structure and optical characteristics of this high transmissive advanced TFT-LCD in detail.

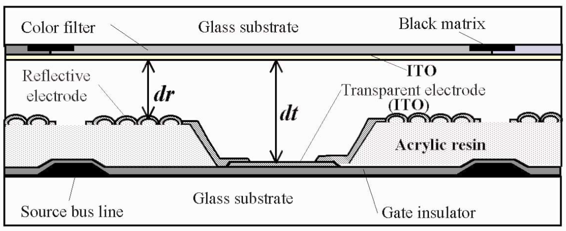
Introduction

Today, transmissive TFT LCDs have been mainly used for digital camera and digital video camera displays. However, transmissive TFT LCDs need to secure at least 350 cd/m^2 or greater screen brightness to achieve good visibility under bright sunlight. It leads the increase of power consumption. On the other hand, transflective TFT LCDs are mainly used for cellular phones. In a transflective LCD, a part of the transmissive area is used as a reflective area, thus the transmissive area decreases. Consequently, the color filter that is 1.5 to 2 times as bright as those of transmissive LCDs have been adopted for achieving high brightness. Thus the color reproduction area that can be displayed is narrowed by transmittance of CFs increases. This is because that higher priority has been given to power consumption than display quality for cellular phones. However, recent cellular phones are equipped with camera functions, and display quality and brightness equivalent to that of digital camera LCDs are required to LCDs for cellular phone. Our group has developed a novel transflective LCD that can achieve transmittance and color reproduction area equivalent to that of transmissive TFT LCDs for responding to the requirements of the market , and we have named it "High-Transmissive Advanced TFT LCD." We describe the structure and display performance of this high transmissive advanced TFT-LCD in detail.

1. Advanced TFT

1.1 Pixel Structure and Its Features

Fig. 1 shows a cross-sectional view of a conventional advanced TFT LCD panel[1) 2)]. The following are two structural features of the advanced TFT LCD.
(1) A pixel is divided into a transmissive area and a reflective area.
(2) The liquid crystal thickness of the transmissive area is about twice that of the reflective area.



Multi gap structure is set to **dr : dt = 1 : 2.**

Fig. 1 Panel structure of conventional advanced TFT LCD

The division ratio of the transmissive area and the reflective area can be optionally set, and if the transmissive area is set bigger than the reflective area, display characteristics with priority given to transmissive mode are obtained, and if the reflective area is set greater than the transmissive area, display characteristics with priority given to reflective mode are obtained. In addition, this division ratio should be determined in accord with the products to which the display is mounted. For example, for clamshell-type cellular phones the priority is given to display quality rather than power consumption, and the latter can be applied to straight-type cellular phones to which priority is given to low power consumption. The transmissive area and the reflective area can be set by forming the transmissive electrode and the reflective electrode inside the pixel electrode on the TFT substrate. In the transmissive area, a transparent ITO electrode that allows light from the backlight to transmit is formed, while in the reflective area, a high-reflectivity aluminum electrode that reflects the ambient light entering from the observer side is formed. In addition, MRS (micro reflective structure)[3)4)] is adopted on the aluminum electrode surface. Therefore, it is possible to design the light so that it scatters within a range of specified angles, and high reflectance can be obtained by efficiently utilizing the ambient light.

On the other hand, the distance of the light that passes the liquid crystal layer of the reflective area and transmissive area can be made equal by making the liquid crystal of the transmissive area about two times thicker than the liquid crystal of the reflective area. When the liquid crystal thickness of the transmissive area is set equal to that of the reflective area and the reflectance is set to the maximum as shown in **Fig. 2** [1], the transmittance is about 50% of the theoretical value. On the other hand, by making the path of the light that passes the liquid crystal layers of the reflective area and the transmissive area equal, the transmittance and reflectance can be achieved the maximum value respectively. In order to form different thickness of liquid crystal between the reflective area and the transmissive area, it makes a bump formed by arranging an insulation layer in only the reflective area on TFT substrate (multi-gap structure on TFT substrate).

However, with this structure, the edge of the insulation layer that corresponds to the boundary section between the transmissive area and the reflective area does not contribute to either transmittance or reflectance. We call this area an invalid area. Since the taper angle of this edge section is 45° on average.

The ambient light reflected at this section is completely reflected at the interface between the glass and air when it is taken out from the panel. In addition, the reflective electrode blocks light from the backlight.

Fig. 3 shows the relation between the transmissive aperture ratio of a 2-inch diagonal TFT LCD and the invalid area. The figure indicates that when the transmissive area is larger than the reflective area, the invalid area increases. In addition, this invalid area increases proportionally as the transmissive area increases. As a result, the actual aperture ratio, which is

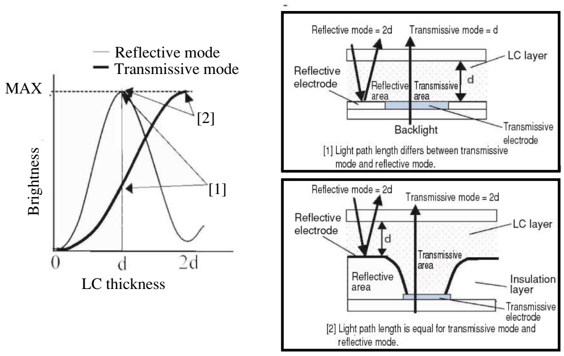


Fig. 2 LC thickness and brightness

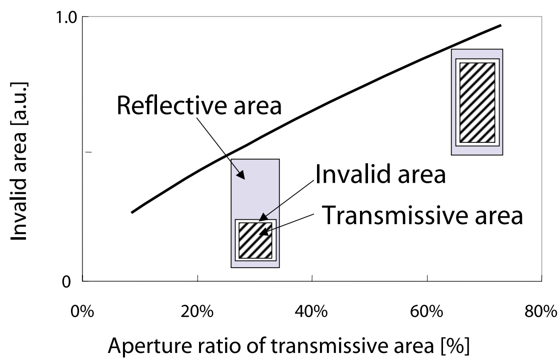


Fig .3 Aperture ratio of transmissive area and invalid area adding the transmissive area to the reflective area becomes lower compared to when the transmissive area is smaller than the reflective area.

2. High-Transmissive Advanced TFT LCD

2.1 Pixel Structure and Features

The above problem can be solved by forming a bump is the cause of complete reflection on the CF substrate. **Fig. 4** is a cross-sectional view of the LCD that the ratio of the transmissive area is higher. **Fig. 4** indicate that, with the structure for forming a level difference on the CF substrate (multi-gap structure on CF substrate), the invalid area that existed at the boundary area between the reflective area and the transmissive area can be reduced. We have named this panel that has a high ratio of transmissive area and has a structure with a bump on the CF substrate as illustrated in **Fig. 4**, the "High-Transmissive Advanced TFT LCD."

Using this technique, we have developed a new LCD that has a transmissive area aperture ratio equal to that of a conventional transmissive LCD and has the MRS reflective electrode structure in the LC cell. **Fig. 5** shows part of the light-shielded area (black area) on the TFT substrate in the transmissive LCD, that is, an example in which the capacitance of storage electrode area (Cs area) is designated as a reflective area. At the position that phase-corresponds to the Cs line on the opposite CF substrate, the bump for a multi-gap is formed using transparent resin. In this way, by forming a reflective area without reducing the transmissive area, it is possible to obtain for indoor use, display quality with high contrast and brightness equivalent to a transmissive LCD. It is also possible to obtain for outdoor use, a bright display that provides excellent visibility by forming the MRS in the cell.

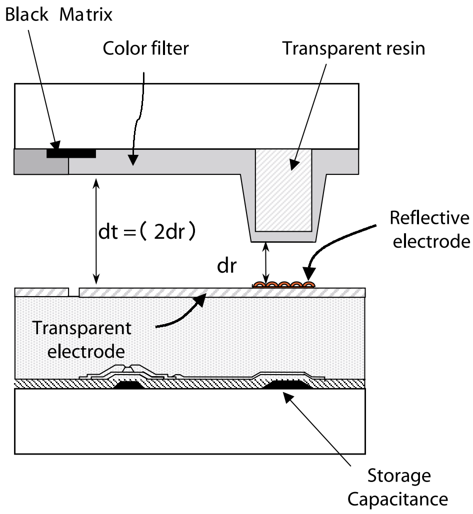


Fig. 4 Panel structure of high-transmissive advanced TFT LCD

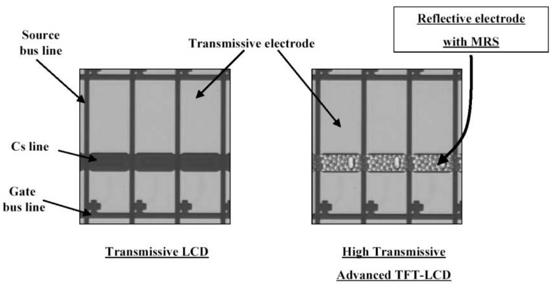


Fig. 5 Pixel structure of high-transmissive advanced TFT LCD

2.2 Color Filter (CF) Structure

In the conventional transflective LCD, there is a problem in which the color reproduction area differs between transmissive mode and reflective mode. That is, when CF for reflective type LCD is used, the color reproduction area of transmissive mode is narrow, and when CF for transmissive type LCD is used, the reflectance is reduced. This is because light from backlight passes through the CF once and ambient light passes twice. Therefore, in order to improve the display quality of the conventional transflective LCD, it is very important to form an optimum CF for reflective mode and transmissive mode, respectively.

There are two methods of manufacturing this kind of CF inexpensively as shown in **Fig. 6**. One is a "pinhole method," in which the CF of the reflective area has a number of pinholes (uncolored CF area). The other is a

"CF overcoat method," which is a structure with the thickness of CF layer of the reflective area reduced compared to that of CF of the transmissive area. For these two methods, when the Y value (brightness) of the CF is varied (in the pinhole method, the number of pinholes is increased. In the CF overcoat system, film thickness is decreased), the color reproduction area of CF overcoat method is wider than that of pinhole method when the Y value of the CF is the same. This is because the ambient light passes through the pinholes directly. The CF overcoat method is suitable for the CF of the transflective LCD because color reproduction area and brightness can be coexisted. We named this method MT-CF structure (multi-thickness color filter). In **Fig. 4**, the CF structure has a bump on the CF side for controlling the LC layer thickness; at the same time, we achieve the MT-CF structure, thus enable high brightness and wide color reproduction area in reflective mode5).

2.3 Display Performance

Table 1 shows the display performance of a 2-inch diagonal high-transmissive advanced TFT LCD for cellular phones. **Photo 1** shows the color filter with the MT-CF structure that was used in this LCD. In this way, it is possible to achieve good visibility and high performance displays under any environment, such as high brightness and high contrast equivalent to the transmissive LCD indoor and high reflectance and high contrast displays outdoors.

Conclusion

By reviewing the panel structure based on the advanced TFT technologies, we have achieved the flexibility of designing ratio between the transmissive area and reflective area in advanced TFT LCD. Thus we are able to respond user needs widely. The high-transmissive advanced TFT LCD technology we developed has the high-quality display image needed for recent cellular LCDs and features compatibility with various application environments. High-transmissive advanced TFT LCDs have already been adopted not only for our cellular phones such as the SH-010, SH251is, but also in digital video cameras such as the Viewcam Z, and are expected to be used in more products. By fusing our original LCD technologies such as HR-TFT technology, the advanced TFT technology of this paper, and 3D LCD technology, with the systematization technique represented by our CG Silicon technology, we can expect to increase our share in the market for mobile LCDs.

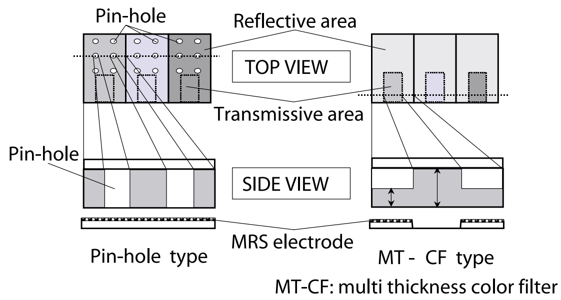


Fig. 6 Color filter structures for transflective LCDs

Table 1 Display specifications

Item	High Transmissive Advanced TFT-LCD	Conventional transmissive LCD
Color filter type	Multi thickness type	Conventional type
Transmittance	12%	12%
Contrast ratio	>200:1	>200:1
Color gamut (NTSC ratio)	27%	27%
Reflectance on BL	2.0%	0.65%
Contrast ratio	17	4
Color gamut (NTSC ratio)	12%	7%

Measure equipment
Transmission: BM5A (TOPCON), Reflection: CM2002 (MINOLTA),
Each panel was placed on LED-backlight.

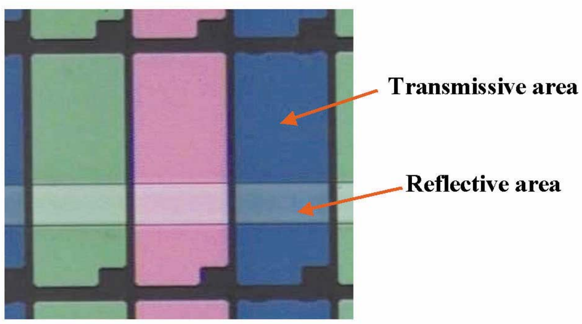


Photo 1 MT-CF structure of a 2-inch TFT LCD

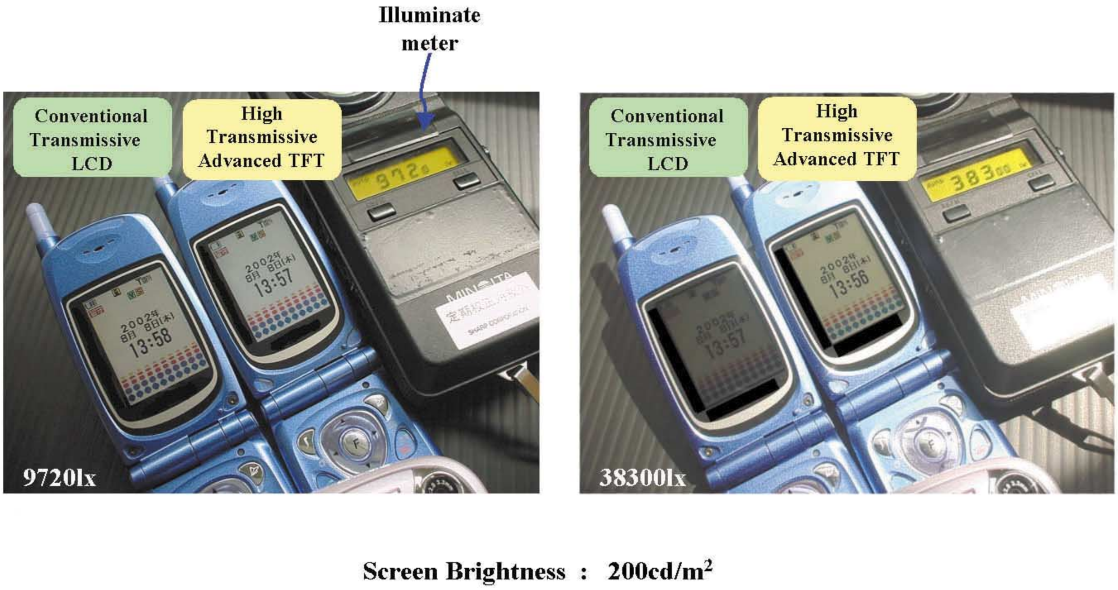


Photo 2 Display image of High-transmissive advanced TFT LCD

Acknowledgments

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