Optical Films for Mobile LCD

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Abstract

Display performance of mobile LCDs has been improved according to broadening of their application. But there are many demands from market, such as contrast improvement (high color reproducibility), higher efficiency of light usage, thickness reduction, widening its viewing angle and so on. To respond them we have been developing many new types of films. In this paper we introduce new high contrast white polarizers for better color reproducibility, and new film construction for higher light efficiency.

1. Introduction

In recently years, due to the drastic advance of mobile equipments, various developments of color LCDs for these applications have been carried out.

In order to reduce the power consumption, reflective or transflective B/W LCDs have mainly been used for mobile application. But in these days, according to increasing the transmission speed and data capacity, the requirement on these LCDs has been changed. These equipments, especially cellular phone and PDA, have to display color still and moving images. So the requirements of higher contrast for high color reproducibility and higher brightness have become stronger. For these demands, transmissive LCDs are suitable.

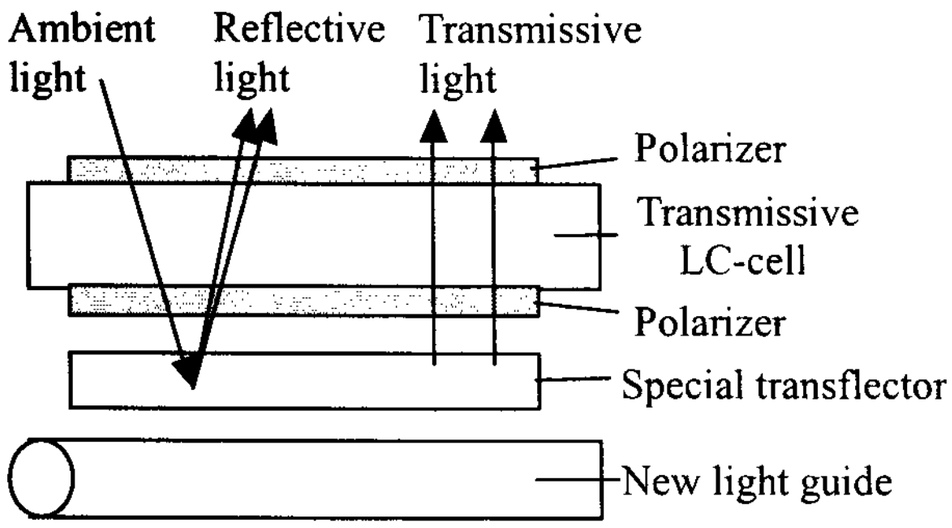


Figure 1 Transflective LCD by use of transmissive panel

But when using transmissive LCDs outdoors, their legibility become worse. So recently, to obtain good legibility in case of both using backlight and ambient light, the methods of using transmissive panels for transflective LCDs by use of new light guide or special transflector like Figure 1 have been studied [1,2].

However, these transflective LCDs still have the following problems that must be improved. In the case of reflective mode, the white pictures have yellowish color, because the high contrast iodine-type polarizer (I-PL) has a little yellowish color and light passes through it 4 times. In the case of transmissive mode, if the transflectors lose or absorb the light, the total efficiency of light usage of transmissive and reflective modes will be lower, and sometimes the white pictures will be colored.

To solve these problems, in this paper a new white polarizer that has high contrast and lower yellowish color, and a new transflector that improves the total efficiency of light usage will be reported.

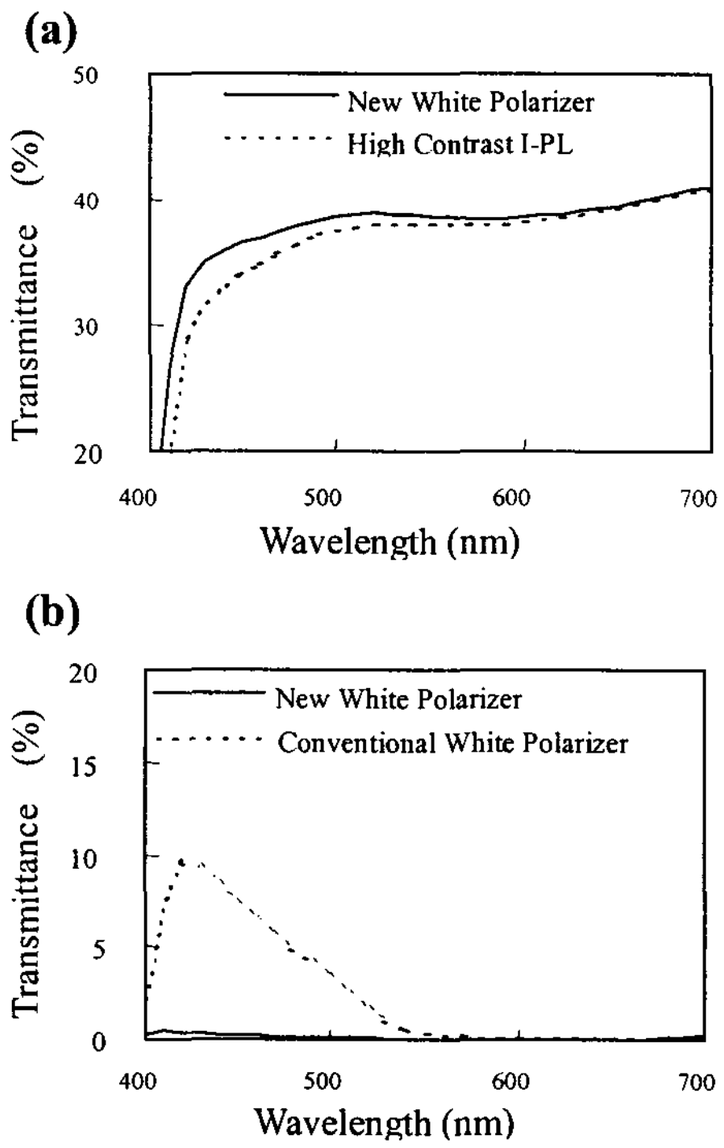


Figure 2 Transmission spectrum of White Polarizer, (a) parallel stare, (b) crossed state

2. New White Polarizer

For TN and STN B/W reflective LCDs, in order to reduce the yellowish color of white state, the so-called white polarizers have been used. But in black state its color is bluish and contrast is low. For B/W reflective LCDs such a white polarizer satisfies

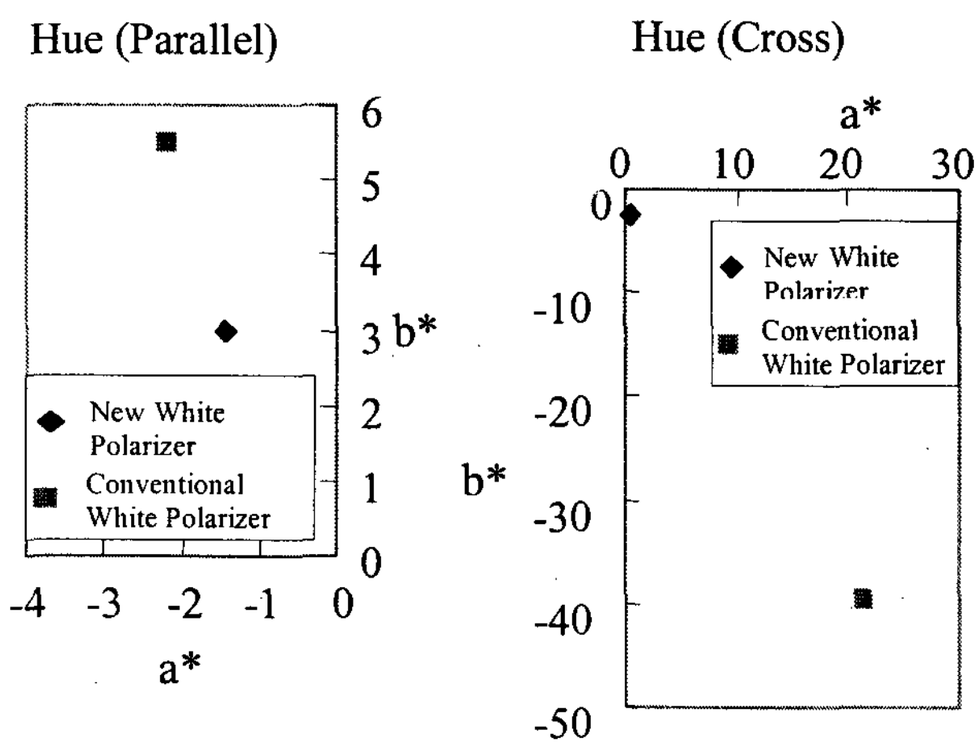


Figure 3 Color of White Polarizer

required legibility, but for color LCDs its performance is not good enough.

By optimizing the composition of the PVA-iodine complexes in PVA, we have succeeded to improve white color compared to conventional high contrast I-PL and black color compared to conventional white polarizer.

Figure 2 shows transmission spectrum of parallel and crossed states of our new white polarizers. Regarding to the spectrum of parallel state, new white polarizer shows flatter transmittance than conventional high contrast I-PL. And in the case of crossed state, the new white polarizer remarkably reduces the light leakage at 400-500nm that conventional white polarizer has. Figure 3 shows their color by a*-b* coordinates.

3. New Transflector

Mobile equipments are used both outdoors and indoors. If they are equipped with conventional transmissive LCDs, they show poor legibility under sunlight and we can hardly recognize the images, because the brightness of image is same as or weaker than that of reflective light of ambient light from the panel surface, black matrix (BM) and the other part of the LCDs.

Figure 4 shows recent transmissive LCD. Due to the use of AR-coated polarizer and low reflective BM (LR-BM) such reflective light is reduced. Then the ambient light goes through the LC-cell and reaches to backlight unit and it is reflected at some elements of backlight, for example, prism sheets that are used to gather light from light guide. But because some of them diffuse the incident ambient light and reflected light, the intensity of the reflected light is too low to display images.

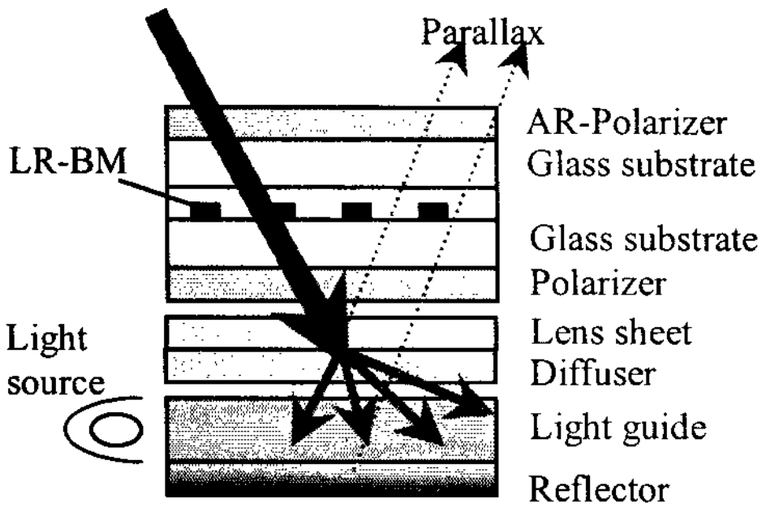


Figure 4 Recent transmissive LCD

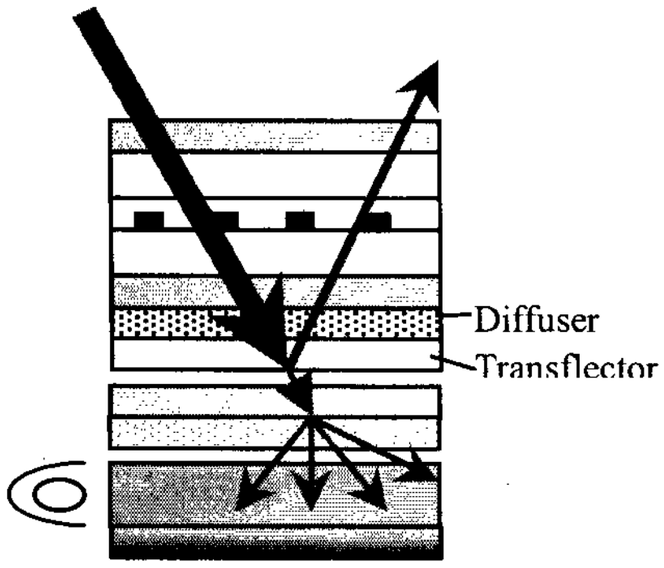


Figure 5 New transflective LCD

In addition, because the ambient light is mainly reflected at the reflector, which is installed under the light guide, the parallax appears.

Therefore in order to increase the efficiency of ambient light usage and to avoid the parallax, it is better to install a transflector over the light guide.

About the transflectors, the conventional ones have relatively higher reflectivity and lower transmittance, and the transmittance is too low to use them for the transflective LCDs that are mainly used in transmissive mode. Then we have developed new transflector that has higher transmittance, and new construction of transflective LCD by use of it as shown in Figure 5.

When we designed the new transflector, following items were taken into consideration, 1) the efficiency of light usage, 2) balance of transmittance and reflectance, 3) using of front scattering layer.

As the reflecting material, metals are inferior in the efficiency of light usage and coloring because of their absorption spectrum properties. So we selected colorless dielectric materials.

When using a transflector, of course, the transmissive brightness declines. Therefore, the balance must be designed carefully. Generally, in the dark environment, the sensitivity of eyes becomes higher, so high transmissive brightness is not always necessary. The legibility under the normal room environment where a certain amount of ambient light exists is necessary to give consideration more. In this case, both the transmission brightness by the backlight and the reflection brightness by the ambient light contribute to display images. We set the transflector reflectivity to 20 - 30 % based on the result of the physical function experiments.

When using a transflector, it is necessary to use the diffuser together to make the display white. But, if the diffuser has the depolarization property, the efficiency of the ambient light usage should decline. Also, the diffusing property itself influences reflection brightness. Therefore, we decided to use the front scattering material that is used for the single polarizer reflective LCDs.

The characteristics of the transflector that was developed in this way is shown in Table 1. The

Table 1 Optical properties of new transflector

Transmission property

Transmittance	L*	a*	b*
72.4%	87.3	+1.0	-0.8

Reflection property

Reflectance	L*	a*	b*
25.9%	55.3	-2.1	+1.5

Table 2 Optical properties of transflector with brightness enhancement film

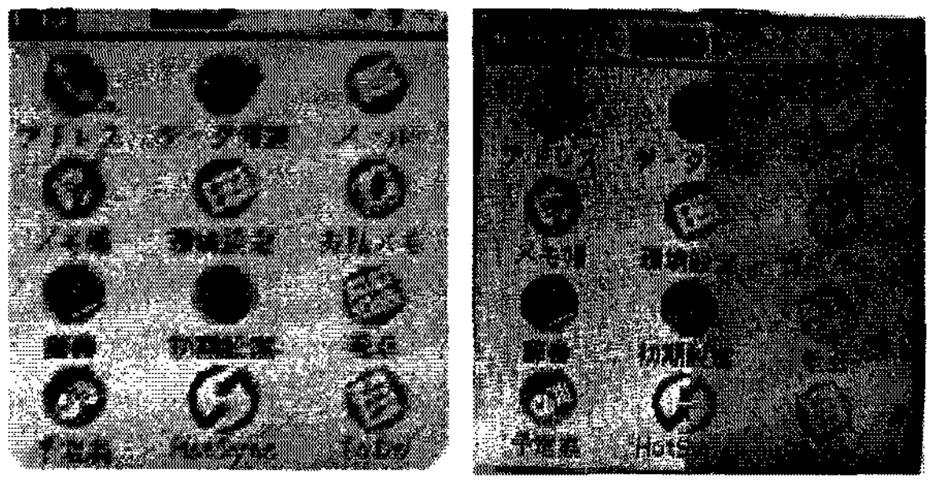
Light source		Brightness (cd/m2)	
Ambient light *)	Backlight	Conventional system	New transflector system
ON	OFF	13.5	22.5
OFF	ON	38.7	31.8
ON	ON	52.5	54.6

*) Ambient light : 500Lux by fluorescent lamp

transmittance / reflectance balance is realized as we designed and also there is few coloring.

The transmittance / reflectance brightness of the system which has a brightness enhancement film laminated with this transflector is also shown in Table 2. When using both environment light and backlight, the brightness of our new transflector applied LCD becomes approximately equal to conventional one. Under the environment that is brighter than this condition, especially outdoors, new transflector gives brighter and better display performance.

The examples of the display in case of using both environment light and backlight, and the display in outdoors are shown in Figure 5.



Under ambient light and backlight

Under sunlight

Figure 6 Photographs of new transflective LCD

4. Conclusion

We have developed new white polarizer and new transflector. By applying those films to transmissive LCDs we can easily make novel transflective LCDs suitable for mobile equipments that have good contrast, color reproducibility and high efficiency of light usage.

Mobile LCDs will be improved more in terms of reduction of power consumption, contrast, color reproducibility, thickness reduction, reduction of surface reflection, broadening the viewing angle and so on. Sumitomo Chemical will continue to develop new optical films to fulfill these requirements.

5. References

[1] A. Tanaka, Monthly Display, 7 (11), p.56 (2001)

[2] J. S. Lim et al., Digest of 2nd International Display Manufacturing Conference, P-51 (2002)