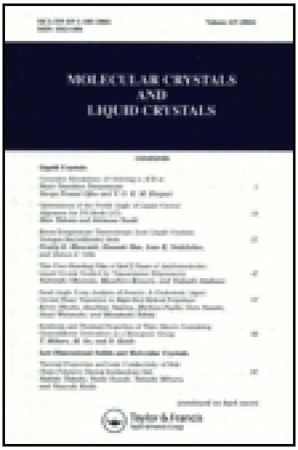

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# Reflective Field-Sequential LCD without Micro-Color Filters using Color Polarizers

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# Reflective Field-Sequential LCD without Micro-Color Filters using Color Polarizers

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We propose a new reflective color LCD using color polarizers based on the confirmed field-sequential LCD (FS-LCD) system. As a result of the experiment, it is that bright color images can be obtained by this reflective LCD.

*Keywords:* color polarizer; field-sequential LCD; reflective LCD color-filterless color LCD

## INTRODUCTION

A field-sequential LCD (FS-LCD) without micro-color filters has recently been reported [1]. This LCD has advantages of high brightness, low power consumption, high resolution and simple fabrication process.

On the other hand, reflective color LCDs [2] have attracted many interests, not only for the portable information systems but also for the desk-top monitor displays because of less eye-fatigue.

Therefore, we propose a new reflective color LCD using color polarizers based on the FS-LCD system. In this system, color polarizers are one of the key components to get bright color images, so that we have specially focused on development of the color polarizers with suitable absorption spectra and high dichroism. In this paper, we describe the design concept and the experimental results.

## EXPERIMENT

Fig.1 shows the structure of a new reflective color LCD which is composed of two parts: two LC-cells with four color polarizers [3] to control spectra and a matrix LC-panel using R-OCB mode to display black and white images. The former two LC-cells only turn the polarized direction of light by 90 degrees or zero. FLC-cell is suitable for these cells. Each two of the four polarizers are stacked with their absorption axis crossed to each other as shown in Fig.1. The R-OCB cell proposed by Uchida, et al. has advantages of gray scale capability, very wide viewing, high brightness and fast response.

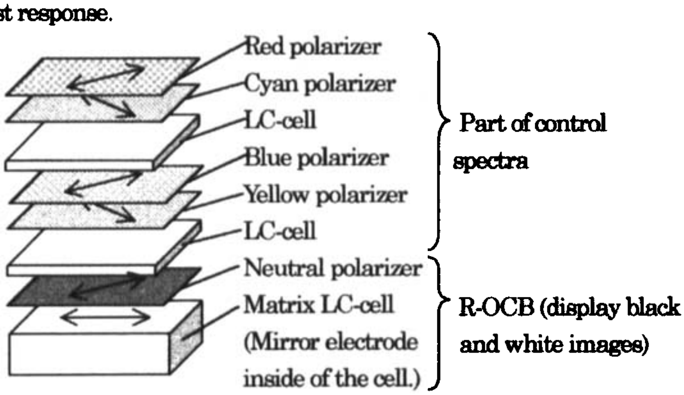


Fig.1 Structure of a new reflective FS-LCD.

Design concepts of the reflective types have to change those of the transmissive types. Because the reflective types do not have the back light with spectra of the three primary color, color property of the display is determined by the spectra of the color filters.

## Structure of the color polarizers with high brightness

We examined to reduce the optical loss to maximize brightness. Standard polarizers are sandwiched between the protective TAC(triacetyl-cellulose ) films whose thickness are about 80$\mu$m. In our reflective FS-LCD, many pieces of TAC films is used as shown in Fig.2(a) because one set of color polarizers are composed of two different color polarizers as shown in Fig.1. In order to reduce the light loss by this polarizers, we reduced the number of TAC films and reduced the thickness of TAC films to 50$\mu$m.

In addition, the TAC film is usually doped with UV-cut material, while it absorbs not only UV-light but also a part of Blue lights. So that, we replaced the UV-cut-TAC film to usual TAC film except the top film as shown in Fig.2(b). Table.1 shows $Y_R$, x and y coordinates of only TAC films in high brightness structure compared with the standard one, where $Y_R$ is the luminous brightness of reflective material as defined by Eq.(1).

$$Y_R = K\int_{380}^{780} P(\lambda)\bar{y}(\lambda)\rho(\lambda)d\lambda, \tag{1}$$

where

$P(\lambda)$: Relative spectral distribution of D65,

$\bar{y}(\lambda)$: Tristimulus values of CIE 1931 standard colorimetric system,

$\rho(\lambda)$: Spectral reflectance distribution of the sample,

$$K = 100/\int_{380}^{780} P(\lambda)\bar{y}(\lambda)d\lambda.$$

It is seen that brightness and chromaticity are considerably improved.

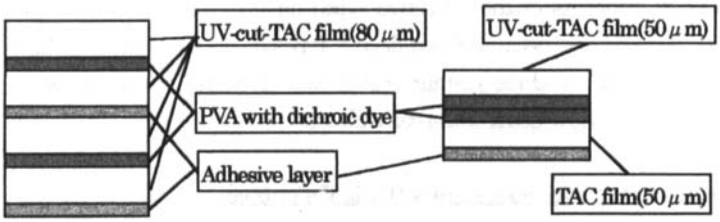


Fig. 2 Structure of the color polarizers with high brightness.

Table.1 $Y_R$, x and y coordinates of only TAC films. (Light source: D65)

| | $Y_R$ | x | y |
|---|---|---|---|
| Standard structure | 95.93 | 0.324 | 0.327 |
| High brightness structure | 97.57 | 0.319 | 0.320 |

## High dichroism of color polarizers

The dichroisms of the polarizers are important to obtain better brightness as well as color purity. Therefore, we examined to improve the dichroism by applying stretching process and high uniaxial alignment technology developed by Sanritz Corporation to the color polarizers. As the result, we succeeded to get high dichroism more than 3.7% higher polarization co-efficiency in comparison with the type as shown in Table.2. Where k1 and k2 are Y of transparent axis and absorption axis and S is orientational order parameter as shown in Eq.(2) and V is the polarization co-efficiency as shown in Eq.(3).

$$S = \frac{A_{\parallel} - A_{\perp}}{A_{\parallel} + 2A_{\perp}}, \quad A_{\parallel} = -\log\left(\frac{k2}{100}\right), \quad A_{\perp} = -\log\left(\frac{k1}{100}\right) \tag{2}$$

$$V = \sqrt{\frac{k1 - k2}{k1 + k2}} \times 100 \tag{3}$$

Table.2 Experimental results for the Blue polarizer.

| | Standard type | High dichroism type |
|---|---|---|
| k1 | 97.33 | 97.26 |
| k2 | 61.24 | 56.65 |
| S | 0.9307 | 0.9425 |
| V(%) | 47.71 | 51.37 |

## Design method to optimize the spectra of color polarizers

We used two colorimetric systems to optimize the spectra of color polarizers. One of them is CIE 1931 colorimetric system for calculation of the chromaticity. The other one is CIE 1976 (L*,u*,v*)-color space for calculation of the saturation as shown in Eq (4). The spectra of dichroic dye were set to adjust R, G and B area of CIE 1931 chromaticity diagram and the dying quantities of the color polarizers were adjusted to get maxim saturation (C*) as shown in Eq (4). Where $Y_0$ is Y of the light source and $u_{0'}$ and $v_{0'}$ are u* and v* of the light source. The light source is D65.

$$\left.\begin{aligned} & L^* = 116\left(\frac{Y}{Y_0}\right)^{\frac{1}{3}} - 16, \quad u^* = 13L^*(u' - u_{0'}), \quad v^* = 13L^*(v' - v_{0'}) \\ & u' = \frac{4x}{-2x + 12y + 3}, \qquad v' = \frac{9y}{-2x + 12y + 3} \\ & C^* = \sqrt{u^{*2} + v^{*2}} \end{aligned}\right\} \quad (4)$$

## RESULT

The optimized spectra determined by the procedure mentioned in the previous section are shown in Fig.3. Table 3 and Fig.4 show their x and y coordinates of the spectra and CIE 1931 chromaticity diagram, respectively.

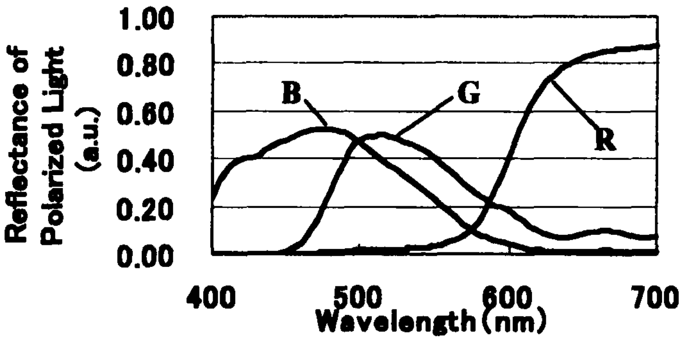


Fig. 3 The optimized spectra for the display.

Table. 3 x and y coordinates of the optimized spectra. (Light source: D65)

| | x | y |
|---|---|---|
| R | 0.642 | 0.351 |
| G | 0.299 | 0.527 |
| B | 0.173 | 0.235 |

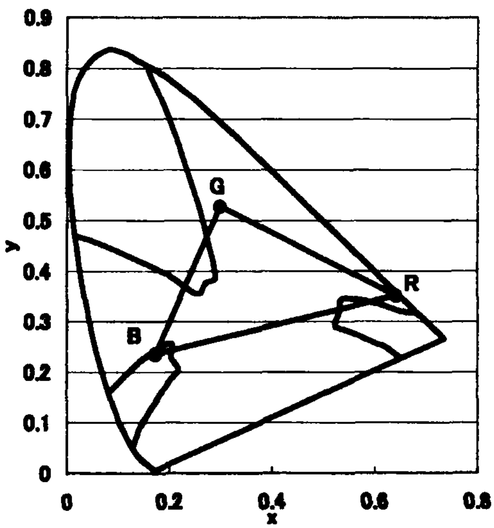


Fig. 4. CIE 1931 chromaticity diagram. (Light source: D65)

The chromaticity coordinates of R, G and B are as good as the usual micro-color filters. Remained problem is insufficient brightness of G and B. It will be improved by optimizing their spectra further more by development of dyes. This reflective FS-LCD using color polarizers is promising because of its three times resolution and less eye-fatigue.

## CONCLUSION

We proposed a new reflective color LCD based on the FS-LCD system and developed color polarizers for the LCD. We confirmed that this LCD had satisfactory color saturation.

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