Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl20

Improvement of White Fluorescent Liquid Crystal Display

R. Yamaguchi [a], K. Moriyama [a] & S. Sato [b]

[a] Department of Electrical and Electronic Engineering, Akita University, Akita City, Japan

[b] Akita Prefecture R&D Center, Akita City, Japan

Version of record first published: 22 Sep 2010

To cite this article: R. Yamaguchi, K. Moriyama & S. Sato (2008): Improvement of White Fluorescent Liquid Crystal Display, Molecular Crystals and Liquid Crystals, 488:1, 210-218

To link to this article: http://dx.doi.org/10.1080/15421400802240631

Mol. Cryst. Liq. Cryst., Vol. 488, pp. 210–218, 2008

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421400802240631

Taylor & Francis
Taylor & Francis Group

Improvement of White Fluorescent Liquid Crystal Display

R. Yamaguchi[1], K. Moriyama[1], and S. Sato[2]
[1]Department of Electrical and Electronic Engineering, Akita University, Akita City, Japan
[2]Akita Prefecture R&D Center, Akita City, Japan

White fluorescent liquid crystal (LC) cells have been demonstrated by mixing two or three dichroic dyes of complimentary or trichromatic fluorescent colors, respectively. The bright white fluorescence was obtained by energy transfers between fluorescent dyes and the fluorescent intensity was controlled by applying the voltage across the LC cell. The brightness was improved by increasing the optical path of the excitation UV light in the cholesteric scattering LC cell. The back scattered light of an ambient white light was also added to the emitting light and the visibility at outdoor or in a bright room could also be increased.

Keywords: cholesteric scattering mode; dichroic ratio; electro optical property; fluorescent dichroic dye; guest host mode; nematic liquid crystal; white fluorescence

INTRODUCTION

Light-emitting type displays, such as a cathode ray tube (CRT), an electro luminescence (EL), and a plasma display panel (PDP), show a high visibility and a wide viewing angle. On the other hand, a conventional liquid crystal display (LCD) is a passive type display which works as a light valve. Some types of emissive LCDs have been also proposed and LCDs containing a small amount of a fluorescent dichroic dye have been reported [1–3]. In such a fluorescence guest host (GH) mode LCD, we have demonstrated on a multi-fluorescent-color switching by stacking different color emitting LC cells [4–7]. We have also reported that the fluorescence intensity is increased using a sensitizing effect in nematic liquid crystals. Green and red

Address correspondence to Rumiko Yamaguchi, Department of Electrical and Electronic Engineering, Akita University, 1-1 Tegata gakuencho, Akita 010-8502, Japan. E-mail: yrumiko@ipc.akita-u.ac.jp

fluorescence intensities can be increased by single and multiple energy transfers under the UV excitation [8–10]. In addition, a white fluorescence has been demonstrated by mixing two complimentary color emitting dyes [11].

In this study, dichroic dyes emitting complementary colors or trichromatic colors are mixed in the nematic or cholesteric LC. A suitable concentration of each dye to emit the white fluorescence is discussed with consideration for the energy transfer between two or three dyes. Electro-optical properties and contrast ratios of the fluorescence intensity were investigated in a cholesteric scattering mode LC cell, compared to the conventional homogeneous GH mode.

EXPERIMENTAL

A blue fluorescent dichroic dye of 2,5-Bis(5-*tert*-butyl-2-benzoxazolyl)-thiophene (BBOT) and a green dye of coumarin-6 (C-6) were prepared as a guest. An yellow dye of Y14 and a red dye of BAPT-BTD were synthesized by Mataka laboratory of Kyusyu University [12]. Host nematic LCs used in this study were ZLI-1083 (Merck) with a positive dielectric anisotropy and MLC-2039 (Merck) with a negative dielectric anisotropy. The choresteric LC was prepared by adding chiral material of cholesteryl nonanoate to ZLI-1083 whose pitch was about 0.7 μm. The cell thickness was about 10 μm in all LC cells.

A UV fluorescent lamp ($\lambda_{max} = 360$ nm, FWHM = 40 nm) was used as an excitation light source. The LC cell was exposed with unpolarized UV light and the polarized fluorescence intensity parallel to the

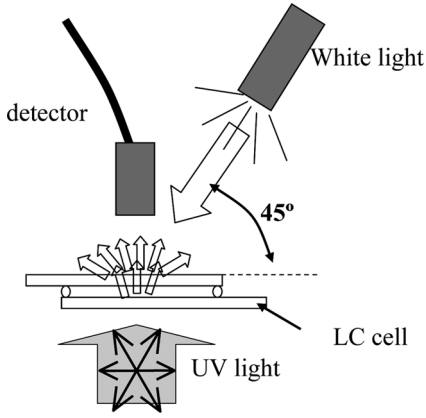

FIGURE 1 Experimental setup for the scattered fluorescent LC cell in a reflection mode.

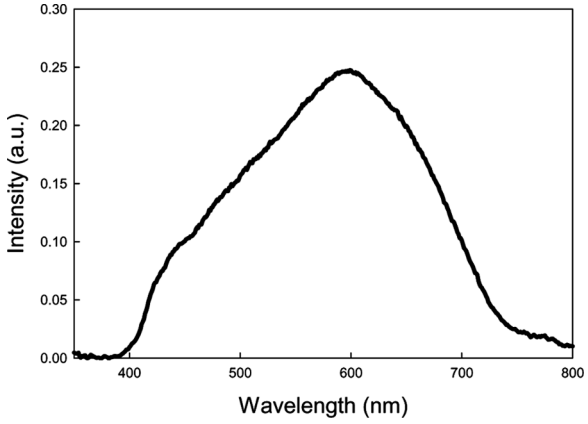

FIGURE 2 Spectrum of the white light from a halogen lamp source.

rubbing direction was detected in the electro-optical property measurement for the homogeneous, twisted nematic (TN) and homeotropic alignment LC cell. Figure 1 shows the experimental setup for the scattered fluorescent LC cell in the reflection mode. A halogen lamp with an IR cut filter was used as an ambient white light source. Figure 2 shows the white light spectrum in this study. The reflection light was detected without a polarizer. The concentrate light angle was about 2 degree.

RESULTS AND DISCUSSION

Mixture of Complementary Colors

Fluorescent spectra of the BBOT and Y14 dissolved in the LC of ZLI-1083 are shown in Figure 3. The concentration of each dye is 0.5 wt%. The fluorescence intensity of BBOT is about 10 times larger than that of Y14, since the absorption spectrum of BBOT widely overlaps with the emission spectrum of the excitation UV light. The yellow fluorescence intensity of Y14 of 0.5 wt% increases more than 3 times by adding BBOT of 0.5 wt% and the blue emission of BBOT is hardly observed. This result suggests that the excitation energy is transferred from BBOT to Y14 in the host LC.

When BBOT of 0.3 wt% and Y14 of 0.3 wt% are mixed in the LC, the peak fluorescence intensity of BBOT is almost the same level as that of Y14, as shown in Figure 4. Both blue and yellow fluorescence intensities increase by increasing the concentration of BBOT ($\sim$1.2 wt%) if the concentration of Y14 is still 0.3 wt%. Therefore, we can observe

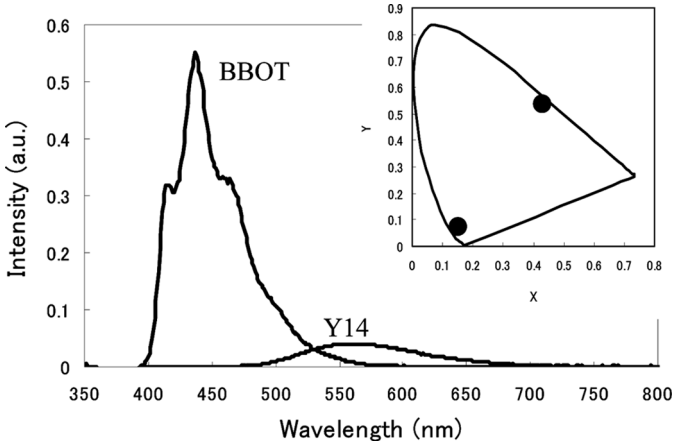

FIGURE 3 Fluorescence spectra of BBOT of 0.5 wt% and Y14 of 0.5 wt% in LC cells, and chromaticity coordinates.

a white fluorescence in each LC cell. The fluorescence intensity of BBOT and Y14 in the homogeneous fluorescent GH LC cell simultaneously decreases by the voltage application across the cell, therefore the white fluorescence color does not change under the voltage application, as shown in Figure 5. Y14 of 0.24 wt% and BBOT of

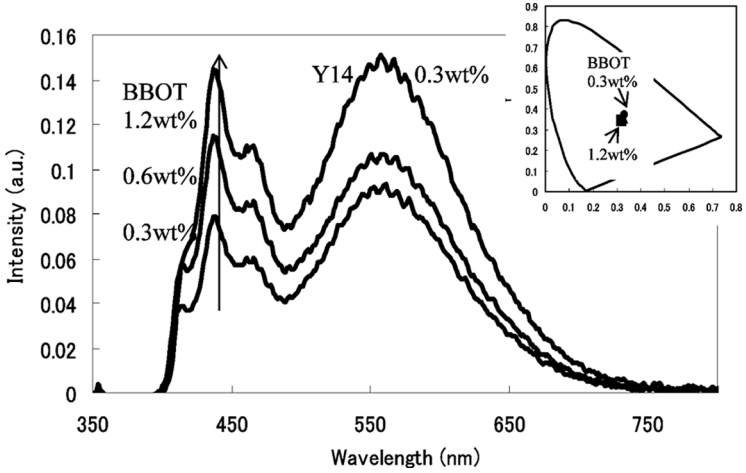

FIGURE 4 Fluorescence spectra of mixtures of Y14 of 0.3 wt% and BBOT of 0.3 ~ 1.2 wt% in the LC cells, and chromaticity coordinates.

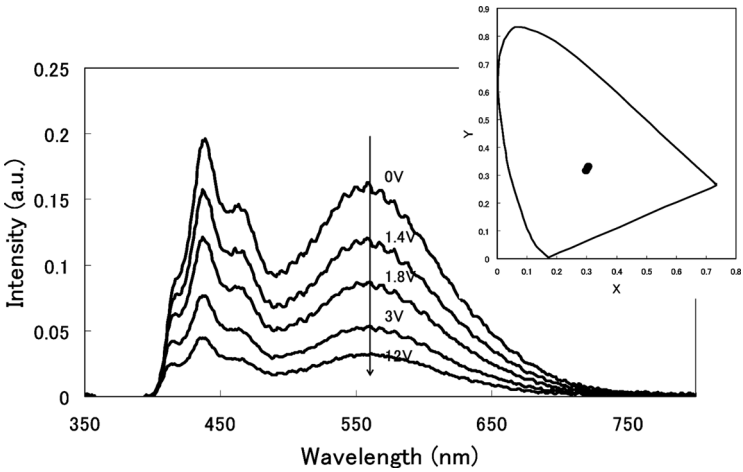

FIGURE 5 Voltage dependence of fluorescence spectra in the homogeneous LC cell with the mixture of Y14 of 0.24 wt% and BBOT of 1.15 wt%, and chromaticity coordinates.

1.15 wt% are mixed in the cell. The contrast ratio of the fluorescence intensities between in the voltage on (12 V) and off state is about 5.

Mixture of Trichromatic Colors

We mixed blue (BBOT), green (C-6) and red (BAPT-BTD) fluorescent dyes are in the host LC of ZLI-1083 which spectra and chromaticity coordinates are shown in Figure 6. The excitation energy is transferred from BBOT to C-6 and BAPT-BTD in the LC. Therefore, the white fluorescence can be obtained when BBOT of 0.3 wt%, C-6 of 0.1 wt% and BAPT-BTD of 0.1 wt% are mixed, as shown in Figure 7. The fluorescence peak intensities of each dye simultaneously decrease with increasing the applied voltage across the homogeneous LC cell. Dichroic ratios of the polarized fluorescence of BBOT, C-6 and BAPT-BTD are respectively about 5, 6 and 7. Therefore, the white fluorescence color slightly becomes bluish with increasing the voltage.

Figure 8 shows electro-optical properties of the white fluorescence intensity in the homogeneous, TN and homeotropic alignment LC cell. The steepness in the TN cell is better than that in the homogeneous alignment cell, since the effect of the polarization rotation disappears by the reorientation under the voltage application. The fluorescence intensity increases with the voltage application in the homeotropic alignment cell using LC of MLC-2039 with a negative dielectric

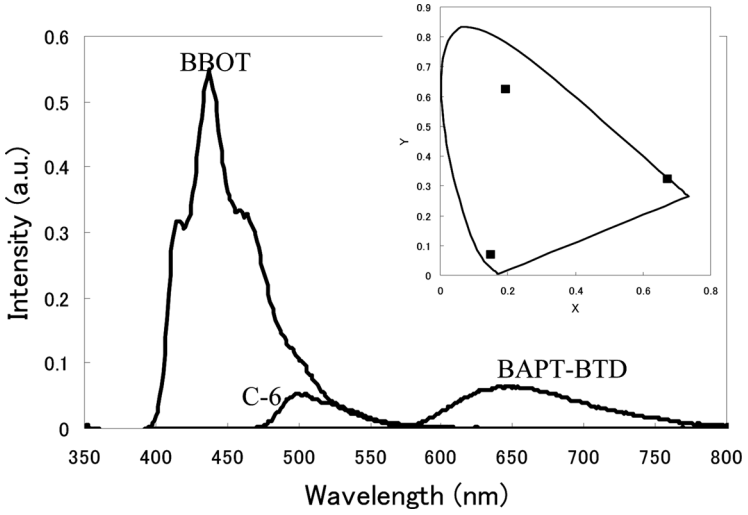

FIGURE 6 Fluorescence spectra of BBOT, C-334 and BAPT-BTD in LC cells and those chromaticity coordinates. The dye concentration is 0.5 wt%.

anisotropy. The contrast ratios are about 6.4, 7.6 and 11.3, when the voltage of 10 V is applied to the homogeneous, TN and homeotropic LC cells, respectively.

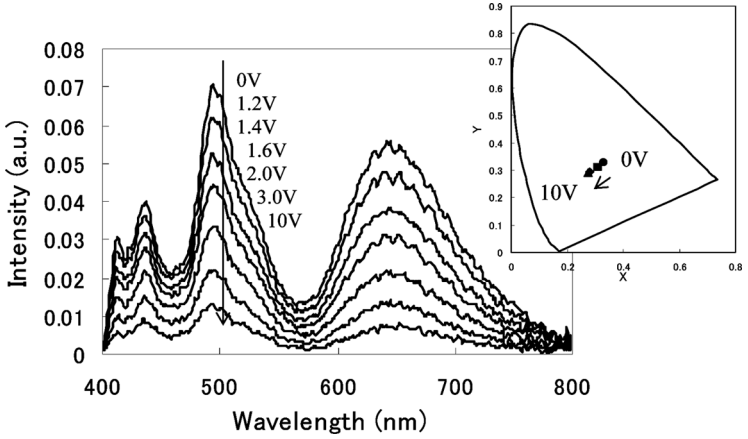

FIGURE 7 Voltage dependence of fluorescence spectra in homogeneous LC cell with mixtures of BBOT of 0.3 wt%, C-6 of 0.1 wt% and BAPT-BTD of 0.1 wt%, and those chromaticity coordinates.

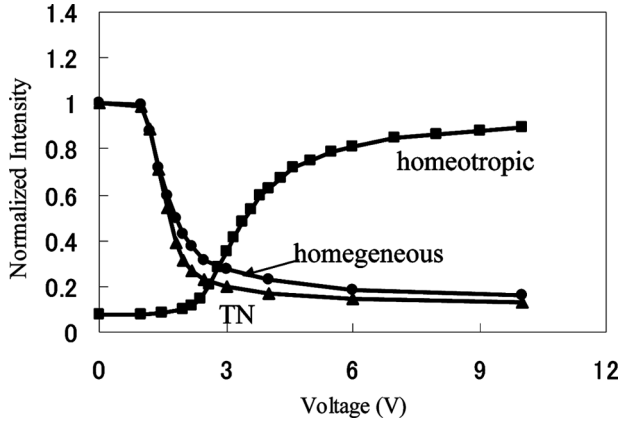

FIGURE 8 White fluorescence intensities in the homogeneous, TN and homeotropic alignment LC cells as a function of applied voltage.

Scattering Mode Using Cholesteric LC

Figure 9 show white fluorescent spectra in the cholesteric LC cell in which three dyes of trichromatic colors are dissolved. Concentrations of three dyes are mentioned in Figure 7. The optical pass of the excitation UV light in the cholesteric LC cell becomes longer by the light scattering effect [13,14]. Therefore, the white fluorescence is about twice brighter than that in the homogeneous cell, as shown in Figure 9(a). The driving voltage of the choresteric LC cell is, however, higher than that of the homogeneous alignment LC cell. When the voltage of 50 V is applied to the cell and choresteric-nematic transition occurs, the fluorescence intensity becomes low and the level is almost the same as that in the homogeneous cell. Therefore the contrast ratio in the cholesteric cell also increases to 11.

Next, the UV lamp is off and then the LC cell is irradiated with the white light from the front side of the cell. The reflection spectra are shown in Figure 9(b). The reflection color in the cell is slightly reddish since C-6 and BAPT-BTD absorb the blue and green lights, respectively. The contrast ratio in the cholesteric LC cell is about 7. Moreover, when the cell is exposed both with the UV light and the white light, the white fluorescence and the reflection light are detected together. Therefore the intensity is 2.5 times brighter than that in the homogeneous cell, as shown in Figure 9(c). The contrast ratio is only 3 in the homogeneous cell, therefore the visibility of the fluorescent homogeneous cell is very poor under the bright room light or at outdoor.

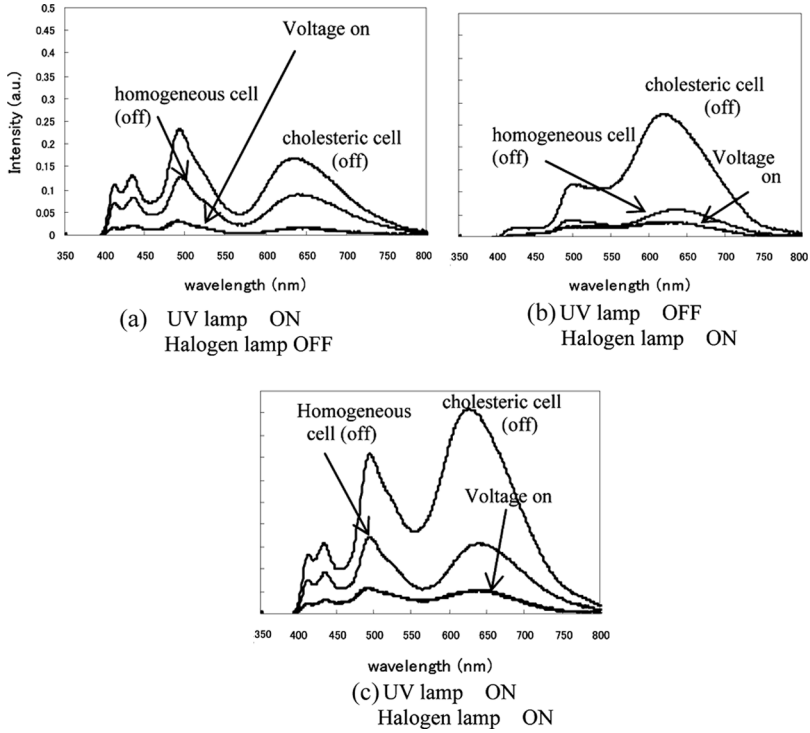

FIGURE 9 Spectra of fluorescent homogeneous and cholesteric LC cells in voltage off and on states.

On the other hand, the contrast is about 9 in the cholesteric cell and the visibility is enhanced.

SUMMARY

Liquid crystal displays emitting white fluorescence are successfully demonstrated. The LC cell containing two or three fluorescent dyes in the homogeneous is exposed with the excitation UV light. The white fluorescence intensity changes by applying the voltage while the color maintains white. The fluorescence intensity in the voltage off state can be increased by using the cholesteric scattering mode. Furthermore the fluorescent cholesteric cell is exposed with the ambient white light, the scattered reflection light adds to the white emitting light. Both the brightness and the contrast ratio are higher than that in the homogeneous cell. The visibility of the fluorescent LC cell at outdoor and in a bright room are successfully improved.

REFERENCES

[1] Yu, L. J. & Labes, M. M. (1977). *Appl. Phys. Lett.*, *31*, 719.
[2] Hochbaum A., Yu, L. J., & Labes, M. M. (1980). *J. Appl. Phys.*, *51*, 867.
[3] Van Ewyk, R. L., O'connor, I., Mosley, A., Cuddy, A., Hilsum, C., Blackburn, C., Griffiths, J., & Jones, F. (1986). *Display*, *7*, 155.
[4] Yamaguchi, R., Ito, Y., Kishida, J., Sato, Y., & Sato, S. (1998). *IDW '98*, 25.
[5] Yamaguchi, R., Kishida, J., & Sato, S. (2000). *Jpn. J. Appl. Phys*., *39*, 5235.
[6] Yamaguchi, R., Nagato, H., & Sato, S. (2000). *IDW '00*, 117.
[7] Yamaguchi, R., Nagato, H., Goto, Y., & Sato, S. (2001). *The 21st IDRC Asia display*, 253.
[8] Yamaguchi, R., Nagato, H., Hafiz, H., & Sato, S. (2002). *IDW '02*, 173.
[9] Yamaguchi, R., Nagato, H., Hafiz, H., & Sato, S. (2004). *Mol. Cryst. Liq. Cryst.*, *410*, 495.
[10] Yamaguchi, R., Hiroshima, D., & Sato, S. (2004). *Mol. Cryst. Liq. Cryst.*, *422*, 105.
[11] Yamaguchi, R., Moriyama, K., Sato, S., Zhang, X., Thiemann, T., & Mataka, S. (2005). *Mol. Cryst. Liq. Cryst.*, *433*, 87.
[12] Zhang, X., Yamaguchi, R., Moriyama, K., Kadowaki, M., Kobayashi, T., Ishi-i, T., Thiemann, T., & Mataka, S. (2006). *J. Mater. Chem.*, *16*, 736.
[13] Sato, S. & Labes, M. M. (1980). *Appl. Phys. Lett.*, *37*, 677.
[14] Sato, S. & Labes, M. M. (1981). *J. Appl. Phys.*, *52*, 3941.