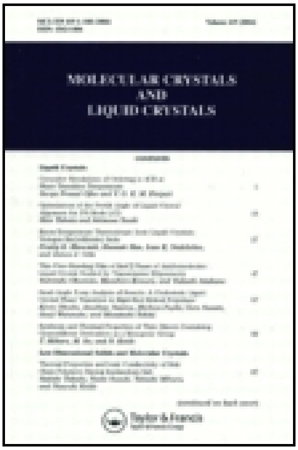

Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl20

The Electro-Optical Property of Guest-Host PDFLC Film Containing Anthraquinone Dye

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Version of record first published: 31 Aug 2006

To cite this article: Chih-Chun Chen, Jier-Fu Lyuu & Jiunn-Yih Lee (2005): The Electro-Optical Property of Guest-Host PDFLC Film Containing Anthraquinone Dye, Molecular Crystals and Liquid Crystals, 433:1, 129-141

To link to this article: http://dx.doi.org/10.1080/15421400590955028

Mol. Cryst. Liq. Cryst., Vol. 433, pp. 129–141, 2005

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421400590955028

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This paper focuses on the light transmission properties of Dye Guest-Host Polymer Dispersed Ferroelectric Liquid Crystal (DGHPDFLC). The DGHPDFLC samples were prepared by using various concentrations of UV curable polymer and 3 wt% blue dichroic dye under various intensities of ultraviolet irradiation. This system can remove a polarizer to achieve better brightness, and improve the transmission of Dye Guest-Host Ferroelectric Liquid Crystal and Polymer Dispersed Ferroelectric Liquid Crystal systems. The results show that the addition of polymer increases the ratio of transmitted light. The prepolymer (NOA65) become fully cured at a higher UV irradiation intensity, and it decreases the transmission of the system.

Keywords: DGHPDFLC; dichroic dye; FLC; guest-host effect; threshold voltage

INTRODUCTION

Heilmeier and Zanoni (1968) discovered the guest-host effect [1] in a liquid crystal display. The guest-host effect has subsequently been reviewed for several liquid crystal displays, including twist nematic (TN) [2] and ferroelectric liquid crystal (FLC) [3] displays.

Polymer-dispersed liquid crystals (PDLC) can be used to produce large-area flexible electro-optic displays [4] without polarizers or switchable light valves; therefore the PDLC system is currently

The authors would like to thank the National Science Council of the Republic of China for financially supporting this research under Contract No. NSC-87-2216-E001-023.

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attracting much interest. As well known, PDLC film still has some unresolved problems, such as high operating voltage and insufficient contrast, due to relatively lower scattering [5]. In 1992, Kitzerow used a ferroelectric liquid crystal, which responds more quickly than TN and exhibits bistable switching, to produce a polymer-dispersed ferroelectric liquid crystal (PDFLC) [6–8].

This investigation reports a Dye Guest-Host Ferroelectric Liquid Crystal (DGHFLC) type of system combined with a UV curing prepolymer. This new system is called the Dye Guest-Host Polymer-Dispersed Ferroelectric Liquid Crystal (DGHPDFLC) [9,10]. This film provides several advantages, which include the potential to reduce a polarizer and increased brightness. The DGHPDFLC films were prepared using fixed dye concentrations (3.0%) and various prepolymer concentrations under various ultraviolet irradiations of 0.5, 1.5, 5 and 10 mW/cm^2 for 180 sec. The properties of transmission and the contrast ratio of the DGHPDFLC obtained using a single polarizer are discussed.

EXPERIMENTAL

(a) Materials and Sample Fabrication

The major material used in this experiment was ferroelectric liquid crystal CS-1024, purchased from Chisso corp. as shown in Table 1. The FLC was mixed with 3.0% by weight of anthraquinone dichroic dye M483 (Mitsui Toastu Dyes Ltd.), whose properties are presented in Figure 1 to form the DGHFLC, and then UV-curable adhesive NOA65 (Norland), whose properties are presented in Table 2, was added in various weight ratios, 2%, 4%, 8%, 16% and 20% by DGHFLC. The inner surface structure of two ITO-coated glass substrates was coated with nylon 6,6 films and rubbed in an anti-parallel direction. The cell gap was approximately 8 μm. After the cell was filled with the mixture by capillary action in the isotropic phase, it was naturally cooled to room temperature to form the SmC* phase. The cell was

TABLE 1 Physical Properties of Ferroelectric Liquid Crystal CS-1024

Phase sequence	$k \xrightarrow{-12^\circ C} SmC^* \xrightarrow{62^\circ C} SmA \xrightarrow{82^\circ C} N^* \xrightarrow{90^\circ C} I$
Spon. Polar. (25°C)	$-46.9\,\mathrm{nCcm^{-2}}$
Title angle (25°C)	25deg
τ (25°C, E = 10 V/μm)	51 μsec
Δn (λ = 546 nm, 25°C)	0.15

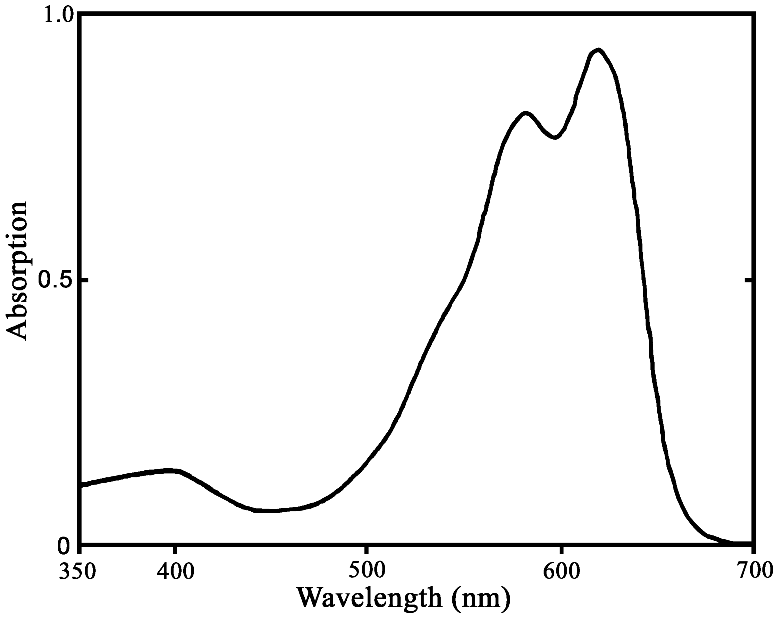

FIGURE 1 The absorption spectra of anthraquinone dichroic dye M483.

TABLE 2 Physical Properties of Prepolymer NOA65

Refractive index (23°C)	1.52
Viscosity (mPa.S)	1000
Tensile (psi)	1500
Modulus (psi)	20000

exposed to 0.5, 1.5, 5 and 10 mW/cm^2 UV irradiation (G-CSUN Co, Ltd., Model: UC-600) for 180 sec to form DGHPDFLC films.

(b) Measurement of Transmission and Contrast Ratio in the DGHPDFLC

Transmission properties associated with wavelengths in the visible range in the dark state and the bright states of the DGHPDFLC film were measured using a Polarizing Micro-spectrometer TFM-120AFT (ORC Manufacturing Co., Ltd.).

The DGHPDFLC system depends on the birefringence of liquid crystals and takes advantage of the bistable mode in which switching occurs between 2θ [11], yielding the dark and bright states. When an applied field interacts with an FLC molecule, the molecule tends to be orientated in the direction $\vec{P}_s$ (+E, dark state). If the field is inverted, then the FLC molecule is reoriented in the direction $\vec{P}_s$ (−E, bright state).

The contrast ratio is calculated from the transmission values of the dark and the bright states, using Eq. (1):

$$CR = T_{on}/T_{off} \quad (1)$$

CR: contrast ratio
T_{on}: transmission of the bright state
T_{off}: transmission of the dark state

RESULTS AND DISCUSSION

(a) Transmission

Figures 2 and 3 show the transmission characteristics of visible light for Dye-M483 and FLC-CS1024 without a polarizer, with a single polarizer and with a crossed polarizer. The minimum transmission

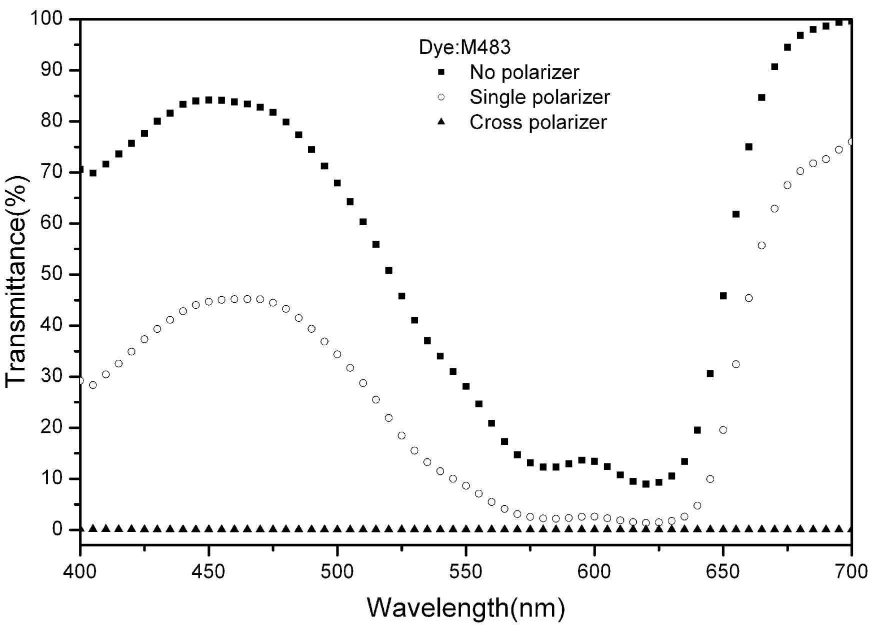

FIGURE 2 Transmission in the visible range of Dye-M483 under no, single, and cross polarizers.

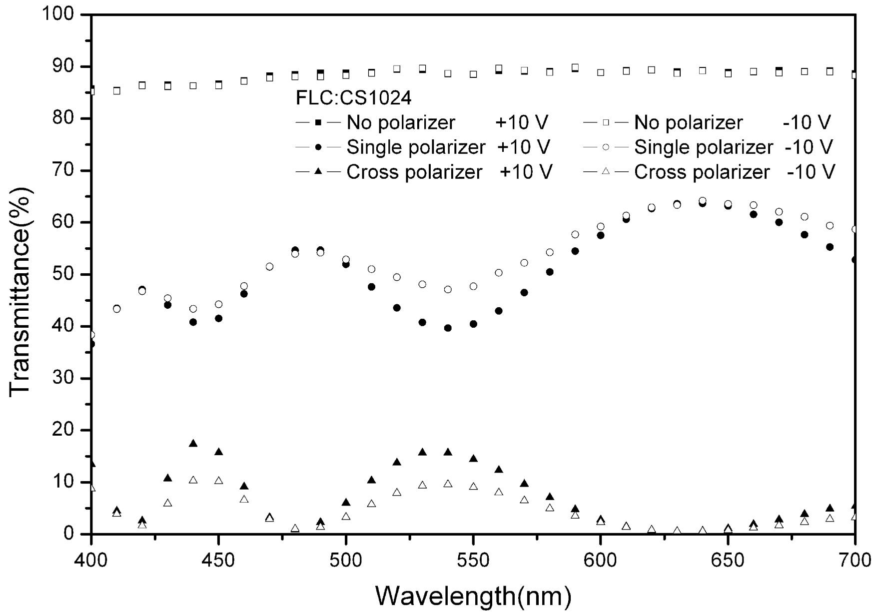

FIGURE 3 Transmission in the visible range of FLC-CS1024 under no, single, and cross polarizers.

of pure dye is approximately 1.4 at 620 nm under a single polarizer. The transmissions of FLC under single and crossed polarizers are antipodes. The maximum transmission under the cross polarizer is approximately 18.

Figure 4 shows the transmission in the visible range of the DGHFLC at a fixed M483–3.0% dye concentration without a polarizer and under a single polarizer. The minimum transmission of the DGHFLC is approximately 20 in 645 nm under a single polarizer. The minimum transmission of the DGHFLC system under the single polarizer exceeds the maximum transmission of pure FLC cell under the crossed polarizer.

Figures 5 to 9 show the transmission characteristics of visible light of DGHPDFLC at various polymer-NOA65 concentrations and fixed M483-3.0% dye concentrations using a single polarizer under UV irradiation with varying intensities. The observed results are discussed in the following.

First, the transmission and absorption wavelengths of the dye molecules in the DGHPDFLC system and pure dye show similar trends. Second, the DGHPDFLC systems transmit better transmission

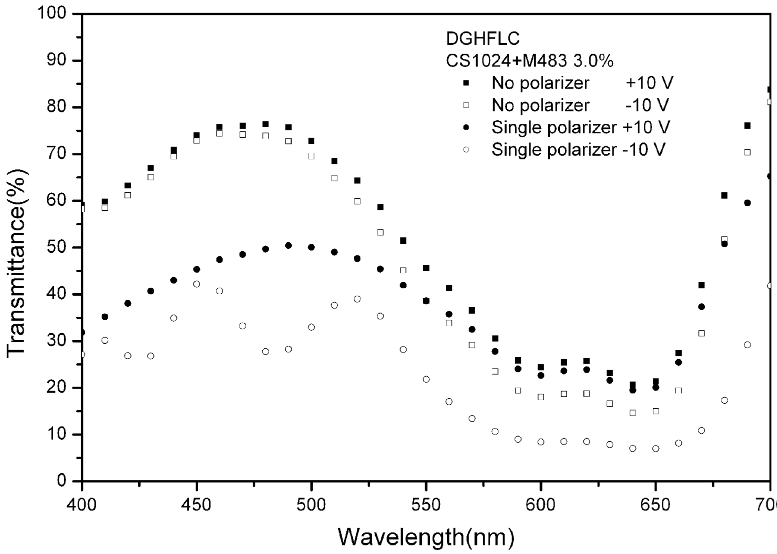

FIGURE 4 Transmission in the visible range of DGHFLC M483-3.0% under no, single, and cross polarizers.

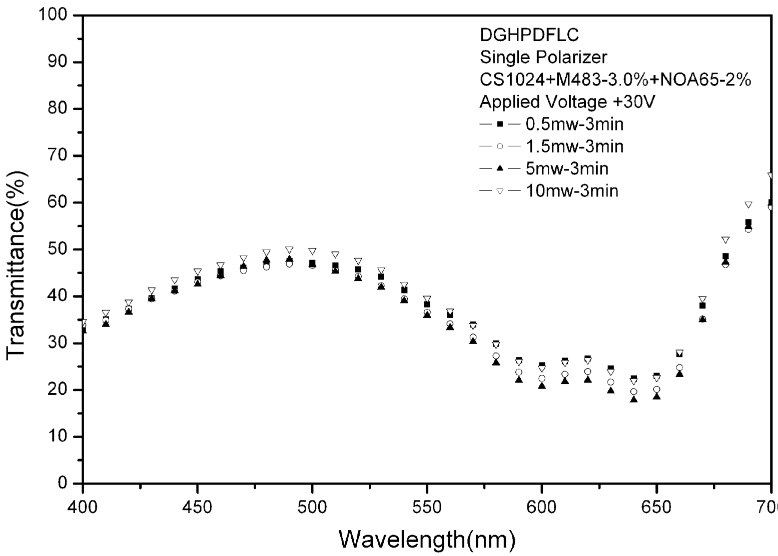

FIGURE 5 Transmission in the visible range of DGHPDFLC NOA65-2% under applied voltage +30 V and various intensities of ultraviolet irradiation with a single polarizer.

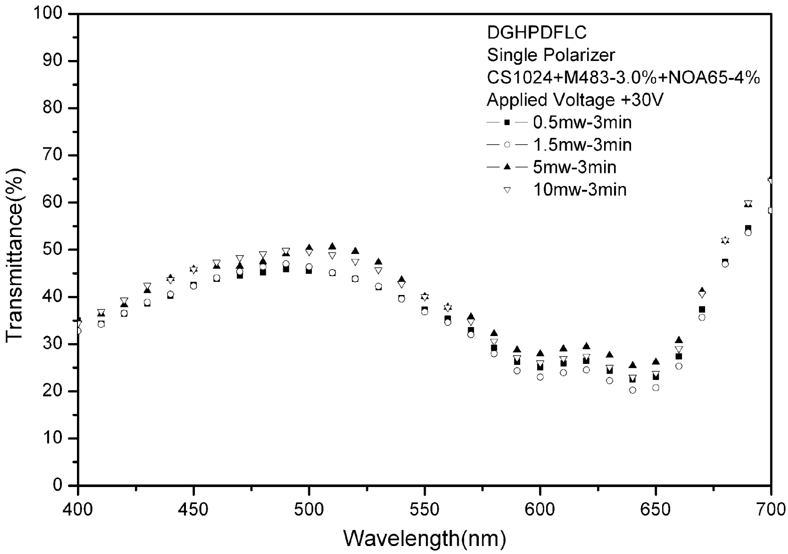

FIGURE 6 Transmission in the visible range of DGHPDFLC NOA65-4% under applied voltage +30 V and various intensities of ultraviolet irradiation with a single polarizer.

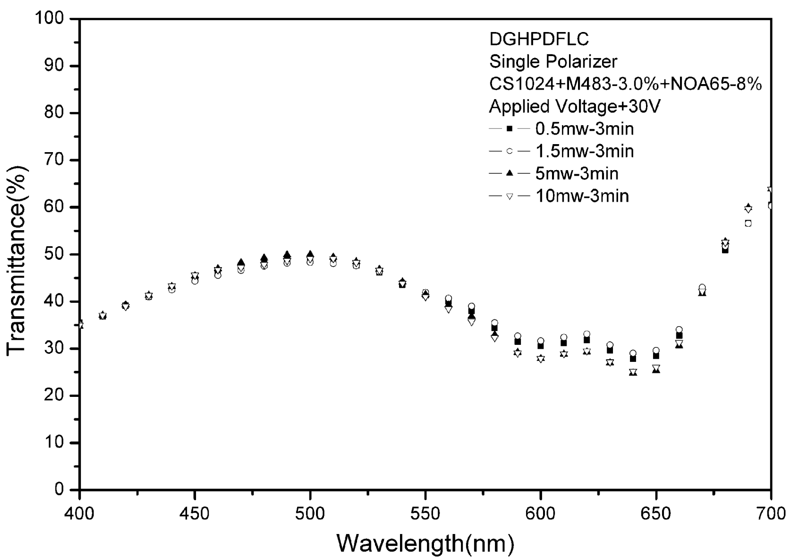

FIGURE 7 Transmission in the visible range of DGHPDFLC NOA65-8% under applied voltage +30 V and various intensities of ultraviolet irradiation with a single polarizer.

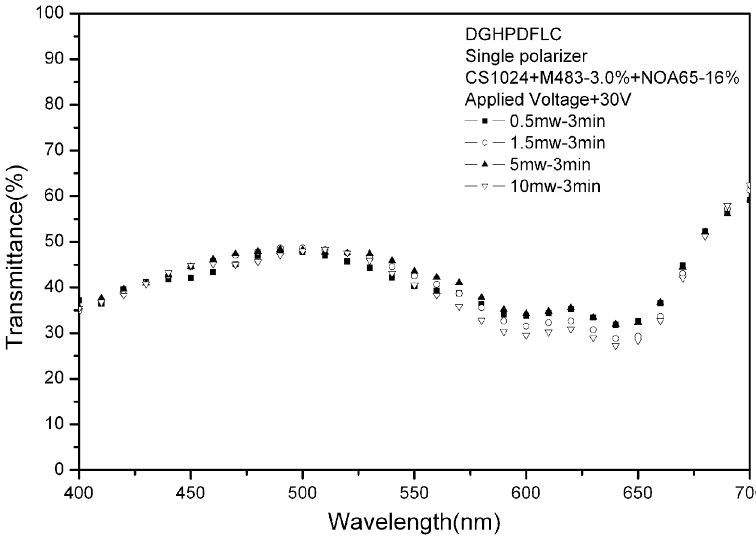

FIGURE 8 Transmission in the visible range of DGHPDFLC NOA65-16% under applied voltage +30 V and various intensities of ultraviolet irradiation with a single polarizer.

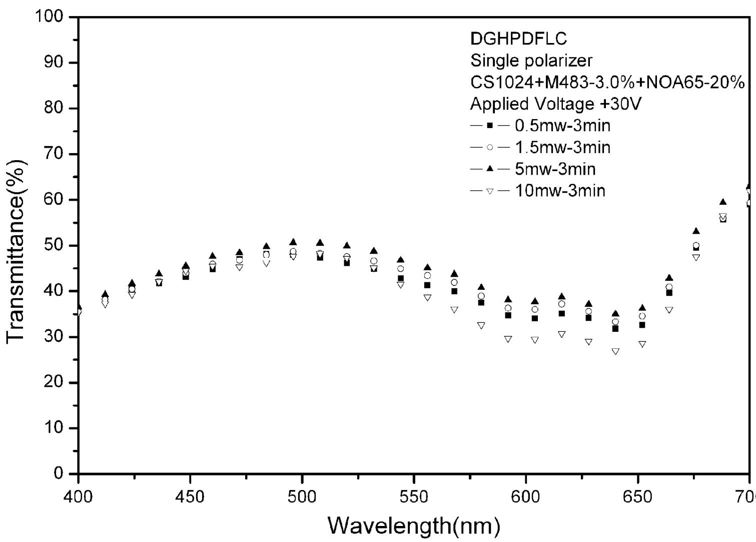

FIGURE 9 Transmission in the visible range of DGHPDFLC NOA65-20% under applied voltage +30 V and various intensities of ultraviolet irradiation with a single polarizer.

than the DGHFLC systems at the maximum absorption wavelength of the dye molecules. Third, the transmission of DGHPDFLC not reaches 45% to 50% at approximately 500 nm, and 65% to 70% at 680 nm to 700 nm. This system thus is better than the PDFLC system [8]. Fourth, different intensities of ultraviolet irradiation produce different levels of transmission when the polymer concentration is fixed. Fifth, at the minimum transmission of the DGHPDFLC systems and at the maximum absorption wavelength of DGHPDFLC molecules (645 nm), the intensity of the ultraviolet irradiation only weakly influences the DGHPDFLC films with polymer content, and the overall DGHPDFLC system exhibits abnormal transmission.

Figures 10 to 13 show the relationship between the transmission and the applied voltage for the DGHPDFLC cell at 645 nm using a single polarizer at room temperature. The results reveal that the threshold voltage of the DGHPDFLC system is only 5 V to 10 V, depending on the polymer concentration, and the increase in the polymer concentration increases the transmission. This result differs from that for the PDFLC system [12,13]. The PDFLC system utilizes the

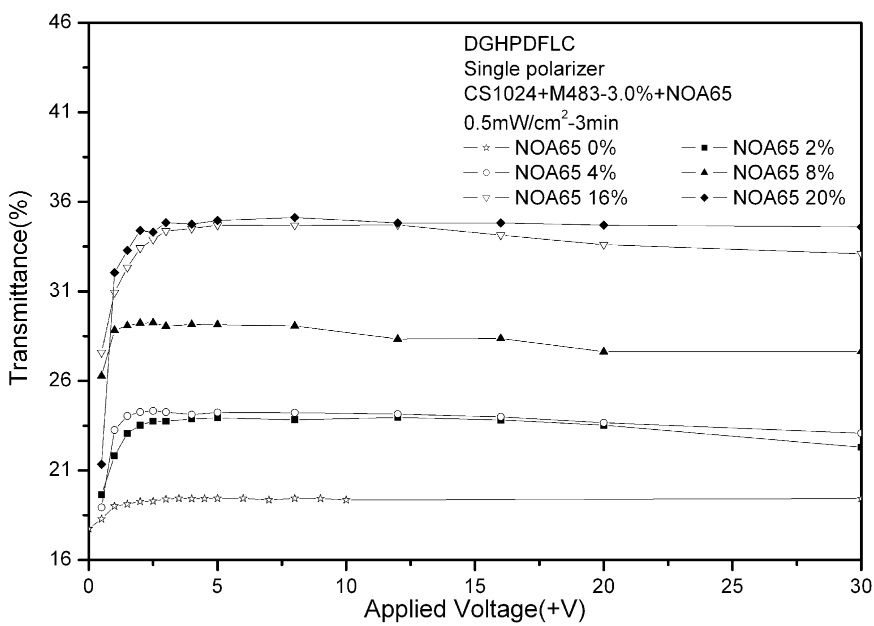

FIGURE 10 The relationship between transmission and positive applied voltage for the DGHPDFLC under various polymer concentrations and fix the UV irradiation of 0.5 mW/cm^2 with a single polarizer at 645 nm.

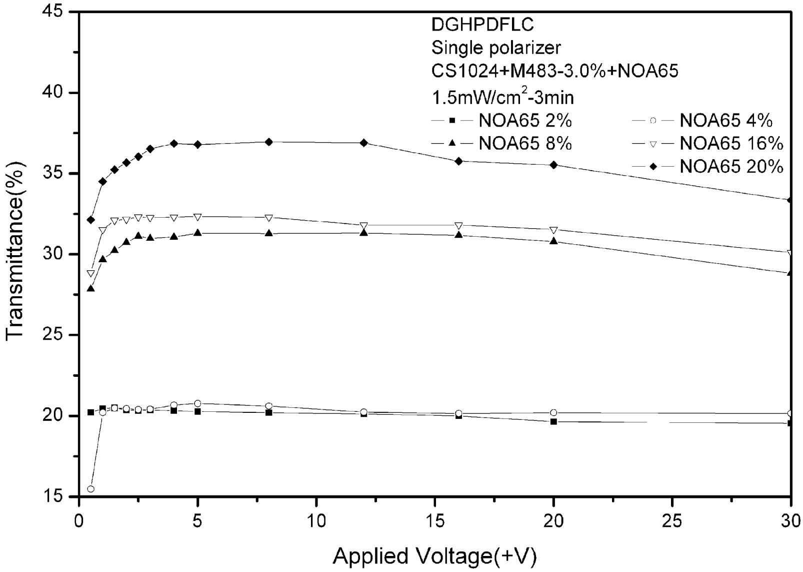

FIGURE 11 The relationship between transmission and positive applied voltage for the DGHPDFLC under various polymer concentrations and fix the UV irradiation of 1.5 mW/cm^2 with a single polarizer at 645 nm.

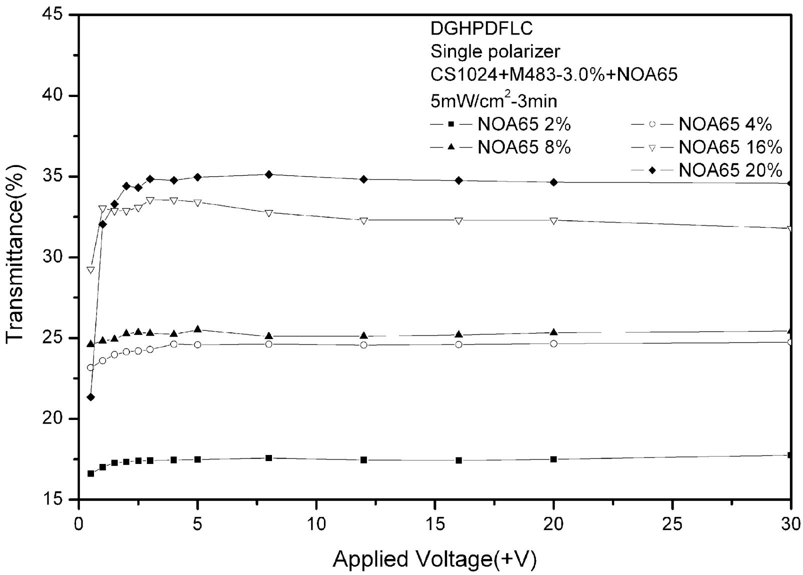

FIGURE 12 The relationship between transmission and positive applied voltage for the DGHPDFLC under various polymer concentrations and fixed UV irradiation of 5 mW/cm^2 with a single polarizer at 645 nm.

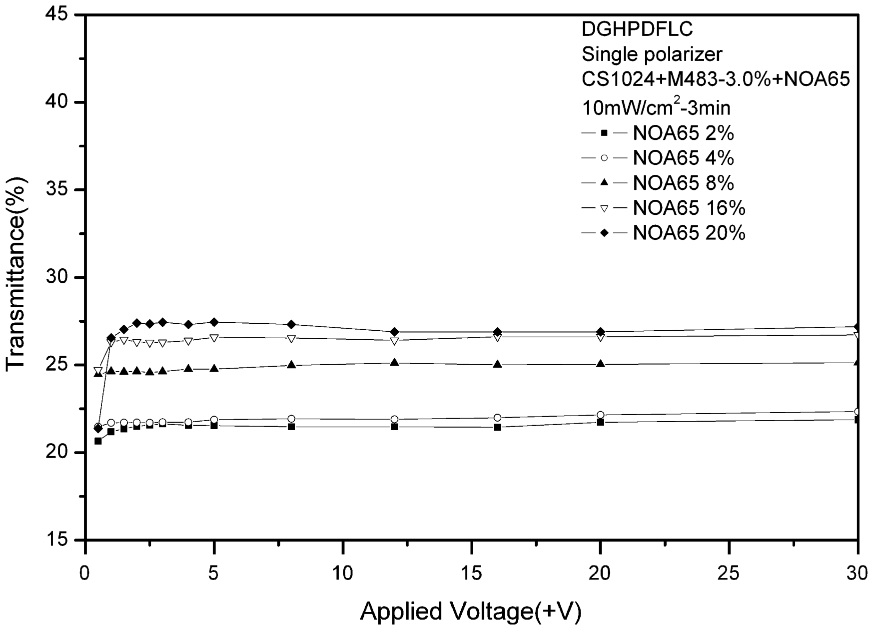

FIGURE 13 The relationship between transmission and positive applied voltage for the DGHPDFLC under various polymer concentrations and fixed UV irradiation of 10 mW/cm^2 with a single polarizer at 645 nm.

birefringence effect of the FLC molecules to yield bright and dark states, and requires two polarizers. Increasing the polymer concentration reduces the transmission. The DGHPDFLC system exhibits bright and dark states, and depends on the bistablility and variation of dye absorption, so a polarizer can be removed by improving the transmission of the DGHFLC and PDFLC systems.

(b) Contrast Ratio

The contrast ratio was defined as the ratio of intensities of transmitted light in the bright and dark states. Figure 14 shows the contrast ratio of the DGHFLC cell. Figure 15 shows the relationship between the contrast ratio and the wavelength of visible light, the DGHPDFLC at 4% polymer-NOA65 concentrations and fixed dye-M483-3.0% concentration, and at an applied voltage of 8 V, using a single polarizer under 5 mW/cm^2 intensities of UV irradiation. The results reveal that the DGHPDFLC system has a higher contrast ratio than the DGHFLC system.

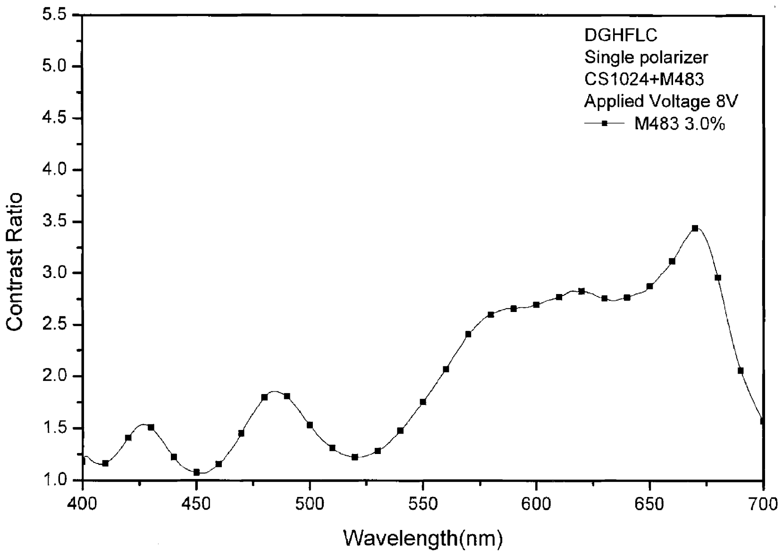

FIGURE 14 Contrast ratio in the visible range of DGHFLC-M483-3.0% under applied voltage of 8 V with a single polarizer.

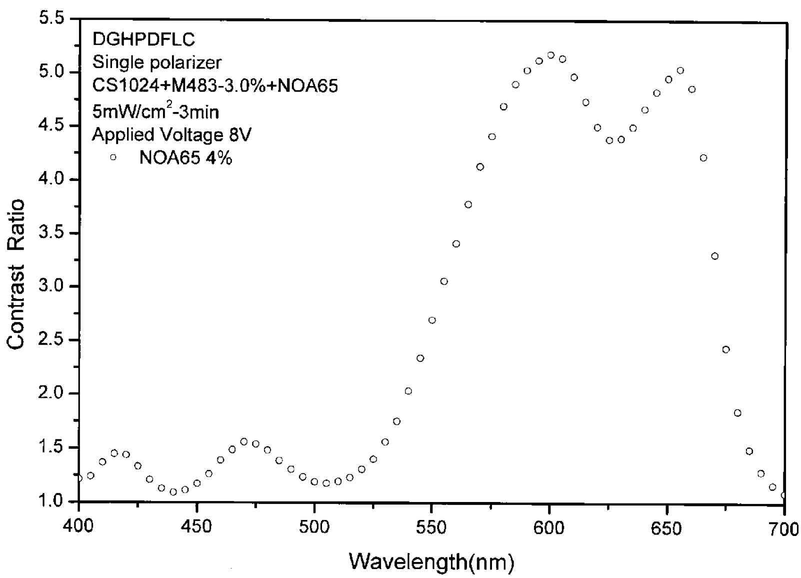

FIGURE 15 The relationship between wavelength and contrast ratio for the DGHPDFLC-5 mW/cm^2 under 4% polymer concentrations and applied voltage of 8 V with a single polarizer.

CONCLUSION

The DGHPDFLC system represents an improvement upon the traditional TN, STN and SSFLC systems, which require two polarizers to generate bright and dark states. Not only can the system achieve better transmission under a single polarizer, but also it yields higher transmission than the DGHFLC or PDFLC systems.

Dispersing polymer in the DGHFLC system to form DGHPDFLC was found to influence the transmission and contrast ratio. Increasing the polymer concentration increases the transmission; the PDFLC system does not exhibit this correspondence. The different intensities of UV irradiation are associated with different transmissions and contrast ratios at the wavelengths of visible light, so suitable polymer concentrations must have proper UV irradiation intensities. An excessive intensity of UV irradiation and an excessive applied voltage can reduce transmission. The threshold voltage of the DGHPDFLC system is not as high as that of the PDFLC system, and it uses much less energy than the PDLC system.

These results indicate that the primary purpose of the Dye Guest-Host Polymer Dispersed Ferroelectric Liquid Crystal Device was achieved because the transmission of the liquid crystal display device was increased.

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