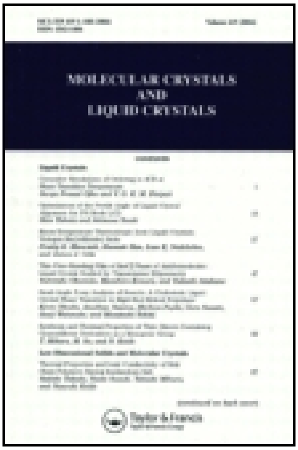

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Effects of the Anthraquinone Dye on the Electro-Optical Properties of Dye Guest-Host Polymer Dispersed Ferroelectric Liquid Crystal

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Effects of the Anthraquinone Dye on the Electro-Optical Properties of Dye Guest-Host Polymer Dispersed Ferroelectric Liquid Crystal

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The effects of the anthraquinone dye on the electro-optical characteristics of DGHPDFLC have been investigated. The results show that PDFLC doped with dichroic dye was found to have no influence on phase separation. When dye concentration is over M483-1.0%, it causes the response time of DGHPDFLC to become slower, the frequency becomes dependent, the tilt angle becomes lower, but, on the whole, electro-optical properties are still very practical.

Keywords: anthraquinone dye; FLC; response time; tilt angle; rotational viscosity; spontaneous polarization

INTRODUCTION

The development of flexible liquid crystal displays [1] using polymer dispersed liquid crystals (PDLC) is currently of high interest, since they have the potential to produce large area flexible electro-optical displays without polarizers and switchable light valves. PDLC film still has some unresolved problems, such as hysteresis in the voltage-transmission curve [2], higher operating voltage and

* To whom should be corresponding.

insufficient contrast due to relatively low scattering [3]. In 1992, H. Kitzerow used a ferroelectric liquid crystal, which has a faster response time and bistable switching to produce a polymer dispersed ferroelectric liquid crystal (PDFLC).

In this article, we report on a new type of PDFLC with added dichroic dye, the so-called Dye Guest-Host Polymer Dispersed Ferroelectric Liquid Crystal (DGHPDFLC). There are several advantages to this film, which include the possibility of reducing a polarizer, higher brightness and color switching. The DGHPDFLC films were prepared using dichroic dye of various concentrations. We will discuss the addition of the dichroic dye and how they influence spontaneous polarization, response time, rotational viscosity, and tilt angle of the DGHPDFLC.

EXPERIMENT

In this experiment, ferroelectric liquid crystal ZLI-4655-100 was purchased from E. Merck Ltd., as shown in TABLE 1. The FLC was mixed with UV-curable adhesive NOA65 (Norland show in TABLE 2) in a 4:1 ratio by weight, and then 0.0%, 0.5%, 1.0%, 2.8% of anthraquinone dichroic dye M483 (Mitsui Toastu Dye Ltd. shown as in FIGURE 1) by weight percent was added. The inner surface structures of two ITO-coated glass substrates were coated with Nylon 6,6 films and rubbed in the anti-parallel direction and with a cell gap of approximately 8μm. After the cell was filled with the mixture by capillary action in the isotropic phase, it was naturally cooled to room temperature i.e. SmC* phase, and then exposed to 0.5mW/cm^2 UV radiation (G-CSUN Co, Ltd., Model: UC-600) for 5 min to form DGHPDFLC.

The spontaneous polarization (Ps) was measured with the Diament bridge method at V=±10 volt (60Hz). The bridge effectively consists of two Sawyer-Tower circuits in parallel. The spontaneous polarization at any temperature is determined from the P-E hysteresis loop through the following equation:

$$P_S = \frac{C_O(V_{OB})}{2A}$$

where A is the active area of the sample, V_{OB} is the maximum peak to peak voltage of the compensated hysteresis loop and C_0 is the value of the fixed capacitor.

TABLE 1 Physical properties of ferroelectric liquid crystal ZLI-4655-100.

Properties	Value
Phase sequence	$k \xrightarrow{<10^\circ C} SmC^* \xrightarrow{61^\circ C} SmA^* \xrightarrow{72^\circ C} Ch \xrightarrow{76^\circ C} I$
Title angle (20℃)	25°
Spon. Polar. (20℃)	+22.6 $nCcm^{-2}$
$\Delta\varepsilon$ (7.5kHz, 20℃)	-1.7
Δn (λ =589nm, 20℃)	0.13

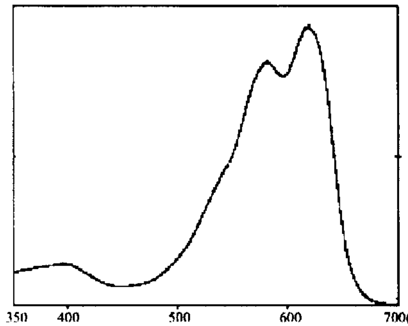

FIGURE 1 The absorption spectra of anthraquinone dichroic dye M483.

TABLE 2 Physical properties of UV-curable polymer NOA65.

Properties	Value
Refractive index (23℃)	1.52
Viscosity (mPa.S)	1000
Tensile (psi)	1500
Modulus (psi)	20000

The response time is defined as the time where the transmitted intensity is changed from 10% to 90% of its maximum change. For our DGHPDFLC device were measured using a He-Ne laser (10mW, 632.8nm) and a fast response photodiode (rise time ~10ns) to record the optical response to a step voltage.

The optical tilt angle was measured by recording the transmitted intensity as the DGHPDFLC was rotated between crossed polarizers. When a switching dc 10-volt is applied, the phase of the output shifts by the induced tilt change of 2θ.

RESULTS AND DISCUSSION

In order to investigate the quality of the polymerization induce phase separation of the DGHPDFLC, we measured the Ps, which should directly correlate with the weight fraction of FLC molecules [4]. Proceeding from the value of Ps = 22.6 nC/cm^2 for the pure FLC ZLI-4655-100, we would expect Ps ≅ 18.08 nC/cm^2 in a PDFLC mixture containing 80% of the FLC, if the phase separation is complete. In fact, PDFLC in our experiment exhibit the similar Ps value which indicates a good phase separation.

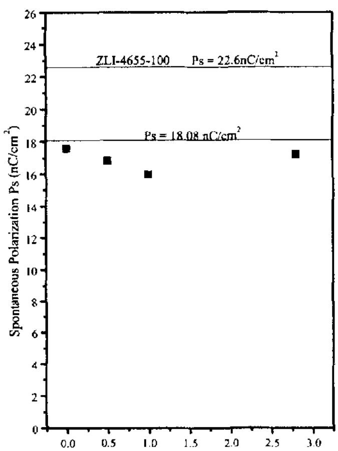

FIGURE 2 M483-dye concentration dependence of Ps of the DGHPDFLC at 25℃.

In FIGURE 2 the addition of dichroic dye was found to have few influence on the phase separation. The spontaneous polarization Ps of the DGHPDFLC decreased with increasing the concentration of dichroic dye M483. It stated that the dichroic dye M483 will affect the FLC molecules alignment, addition of the dichroic dye will course the FLC molecules alignment random and the dipoles can not unidirectional.

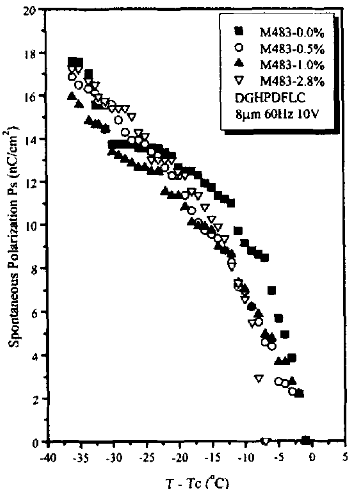

FIGURE 3 Temperature dependence of Ps of the DGHPDFLC at different M483-dye concentration.

The plots of Ps versus temperature for the DGHPDFLC at different M483-dye concentrations have shown in FIGURE 3. In the SmC* phase, Ps of the DGHPDFLC increased with increasing $|T\text{-}Tc|$. The temperature dependence of the polarization can be expressed as following power law equation [5]:

$$Ps = Ps_0 \times (Tc - T)^{\beta}$$

where T is actual temperature, Tc is the phase transition temperature of SmA* to SmC*, Ps_0 and β are material constant. It is interesting to note that the theoretical models for a material with a SmA* to SmC* phase transition predict the value of the exponent to be 0.5 [6]. In our result, the value of exponent for DGHPDFLC increased with increasing the dichroic dye concentration; maybe the dichroic dye concentration increased cause the behavior of phase transition changed.

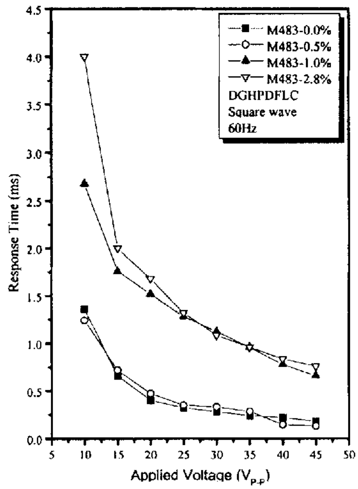

FIGURE 4 Voltage dependence of response time of the DGHPDFLC

FIGURE 4 shows the relationship between response time and the applied voltage for fixed applied 60Hz square-wave ac voltage on the DGHPDFLC. The response time of the DGHPDFLC decreased with the applied field strength. When the concentration of mixed dichroic dye over M483-1.0%, the ability of the extra electric field switch of the FLC in the polymer matrix decreased. With an increase of M483-dye concentration in the DGHPDFLC that the viscosity of the FLC in the polymer matrix will increase and response time will be slower.

FIGURE 5 shows the relationship between the response time and the applied frequency for fixed applied 10-volt (peak to peak). The response time was found almost frequency independent in M483-0.5%. Thus, Doping of a slight dye reveals no significant change in the switch ability of the FLC molecules in the polymer matrix. On the other hand, response time of M483-1.0% and M483-2.8% DGHPDFLC shows a sharp decreased tendency as increasing the applied frequency. That is due to the ion effect, the voltage applied on FLC molecules in the polymer matrix is smaller than the actual voltage; thus, the response time was increased in low applied frequency. In high frequency, the ion effect was disappeared, the voltage applied to FLC molecules in the polymer matrix is the same with actual applied voltage, which leads the response time decreased with increasing the applied frequency [7].

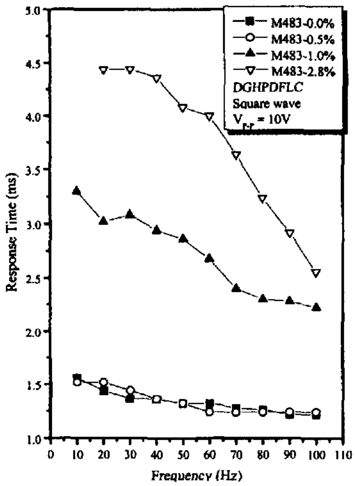

FIGURE 5 Frequency dependence of response time of the DGHPDFLC at different M483-dye concentration.

In this study, the optical response method [8] has been employed to determine the rotational viscosity in the SmC* phase associated with the motion of the tilted molecule along the cone of the azimuthal angle. It is calculated by using equation:

$$\gamma_\phi = \frac{P_s \cdot \mathrm{E} \cdot \tau}{1.8}$$

where E is electric field strength within the DGHPDFLC medium, P_s is the spontaneous polarization, τ is response time.

In FIGURE 6, the rotational viscosity of the DGHPDFLC increased with increasing M483-dye concentration. The rotational viscosity of the DGHPDFLC was raised through the inclusion of the dichroic dye M483 from 145 to 478 mPaS at 25℃, which show three times difference between M483-0.0% and M483-2.8% of DGHPDFLC. at different M483-dye concentration.

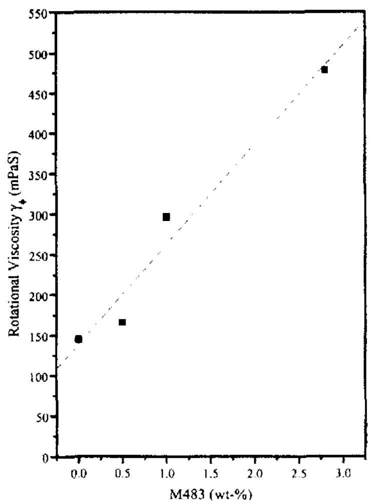

FIGURE 6	M483-dye concentration dependence of rotational viscosity of DGHPDFLC at 25℃

The optical tilt angle dependence of dichroic dye concentration was shown in FIGURE 7. Many application of FLCs requires that the phase have an optical tilt angle of 22.5 or 45° depending on the configuration of the device. However, the optical tilt angle varies with temperature and is not constant. Therefore, it is important for the application to measure the optical tilt angle. In FIGURE 7, we can found that the optical tilt angle was slightly decreased with increasing the dichroic dye. The optical tilt angle of DGHPDFLC dependence of $|T-Tc|$ was shown in FIGURE 8, the optical tilt angle increased with increasing $|T-Tc|$, and it will be deceased to zero on the phase transition temperature of SmA* to SmC*. The relationship of optical tilt angle and temperature can be expressed as following power law equation [5]:

$$\theta(T)=\theta_0\times(Tc-T)^{\beta}$$

where $\theta(T)$ is the optical tilt angle of actual temperature, T is the actual temperature, Tc is the phase transition temperature of SmA* to SmC*, θ_0 and β is constant.

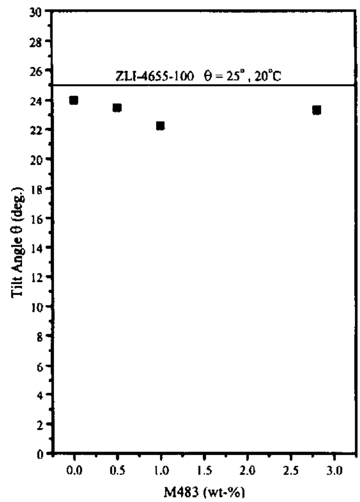

FIGURE 7 M483-dye concentration dependence of tilt angle of the DGHPDFLC at 25℃.

We can found via the power expression that the θ_0 decreased and β increased with increasing M483-dye concentration in the DGHPDFLC. In the theoretical models predict the values of the exponent to be 0.5. Other modified models give a value of the exponent of 0.37. The experimentally observed value β is 0.375 and 0.436 for M483-0.0% and M483-0.5% which are a close agreement with these theoretical prediction.

The FIGURE 9 (A)~(D) show the relationship between tilt angle and applied voltage at different temperatures for M483-0.0%, M483-0.5%, M483-1.0%, and M483-2.8% respectively. The optical tilt angle was independent of applied voltage after applied dc 5-volt at different dichroic dye concentration for fixed temperature.

CONCLUSION

The PDFLC doped with dichroic dye to produce DGHPDFLC was found to have influence on the Ps, θ and phase separation. When the

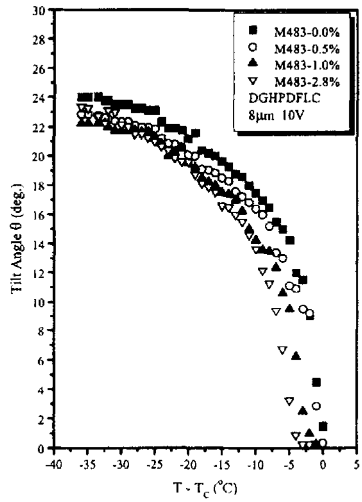

FIGURE 8 Temperature dependence of tilt angle of the DGHPDFLC at different M483-dye concentration.

concentration of the added dichroic dye was over M483-1.0%, it not only influenced the response time, especially the dependence of the applied voltage and frequency, but also made the rotational viscosity higher. Below the Tc, the value of Ps increased with decreasing the temperature, and the optical tilt angle was found independent of applied voltage after applied dc 5-volt. We also found that the optical tilt angle and the value of Ps of DGHPDFLC agree with power law at the narrow dichroic dye concentration.

ACKNOWLEDGMENTS

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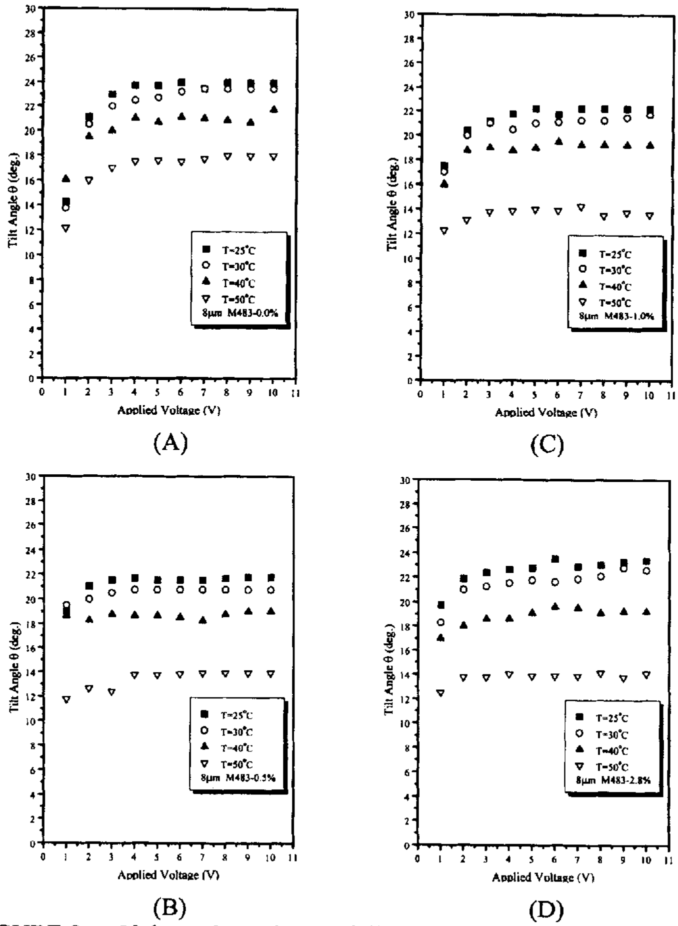

FIGURE 9 Voltage dependence of tilt angle for DGHPDFLC (A) M483-0.0% (B) M483-0.5% (C) M483-1.0% (D) M483-2.8% at different temperature.

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