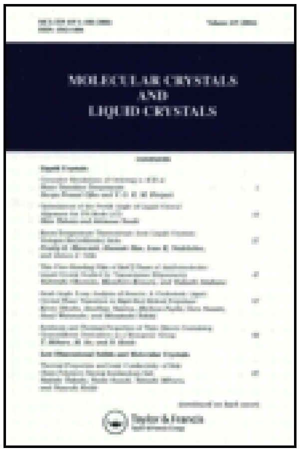

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ELECTRO-OPTICAL PROPERTIES OF CHOLESTERIC LIQUID CRYSTALS AND POLYMER COMPLEX

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Abstract A set of liquid crystals and polymer complex (LCPC) films which have different polydomain focal conic textures and different polymer wall were prepared. The electro-optical properties of cholesteric liquid crystals and polymer complex were investigated using OS - 6411C Digital Storagescope with He-Ne laser and candescent light. These LCPC films may have various threshold-voltage, electro-optical response time and contrast ratío which depend on LCPC's composition, especially the focal conic liquid crystal textures in polymer matrix and polymer wall effect. Among these, the best LCPC film was developed which has a very low driving-voltage, quick response time and high contrast ratio. The results reveal that the cholesteric twisting power and polymer wall effect are most important factors for electro-optics of LCPC films.

INTRODUCTION

Liquid crystals and polymer complex (LCPC) or called polymer dispersed liquid crystals (PDLCs) and polymer-dispersed liquid crystals (P-DLCs) are new kinds of electro-optical materials which are attractive to many researchers since these materials have a lot of advantages, such as non-polarizer usage, ease of fabrication and manufacture of large area display devices and light shutters, very quick response in electro-optics and also low driving voltage[1-3]. To study and develop LCPC materials for light shutter and display applications, one must consider about the three important electro-optical properties, which are driving voltage, response time and the contrast ratio. It is well known that polydomain focal conic texture of cholesteric liquid crystals (ChLCs) scatters a light tremendously. To improve the electro-optical properties, one must control the polydomain texture of LCPC for scattering light. One point to attempt this is to control the cholesteric twisting power, and another is to introduce the polymer wall effect.

In this paper, an attempt has been done to improve the turbidity and decay-time (τ_d) of LCPC films by controlling the multi-cholesteric twisting power and the polymer wall effect, and a newly developed multi-twisting power ChLCPC (abbreviated multi-ChLCPC, hereafter) which has much better electro-optical properties will be introduced. We would rather call LCPC than PDLC films mainly because the polymer concentration in our system is much lower than others.

EXPERIMENT

LCPC films are formed by polymerization induced phase separation. The ratios of Ch-NeLCs [a mixture of nematic liquid crystals (NeLCs) + ChLCs)] and multi-ChLCs [a mixture of NeLCs + ChLCs + smectic *C liquid crystals (Sm*CCLs)] were first got and blended with oligomer (methyl-methacrylate) . A homogeneous solution of the liquid crystals (LCs) and oligomer was firstly sandwiched in two Nesa glass plates with a spacer of thickness(7.5μm-25μm), and then polymerized under UV light for 4-5 min. The solution would become a two phase system. The polydomain ChLCs gradually appeared during the polymerization. Thus, the very small size and cone shaped LC grains covered with thin polymer films were formed within the cell. The electro-optical properties of LCPC were investigated using OS-6411C Digital Storagescope with He-Ne laser or candescent light as the light sources.

RESULTS AND DISCUSSION

THE ELECTRO-OPTICS OF MULTI-CHOLESTERIC TWISTING POWER LC WITH POLYMER

It is well known that when a little pure ChLCs is added to NeLCs, the mixed LCs will become ChLCs. The electro-optical properties of ChLCPC films have been discussed before[4-6]. Here, the experimental results for the multi-ChLCPC film which contains a small amount of Sm*CLCs besides ChLCs will be introduced, compared with those of ChLCPC. Fig.1 shows the difference of transmittance (T) and response time, both of rising time (τ_r) and decay time (τ_d) between Sm*CChLCPC and ChLCPC with the voltage at 500Hz. The components of them are shown in Table 1. It was found that a little Sm*CLCs (0.2 %) could not only greatly increase the transmittance of LCPC films in the ON state but also improve the quick response time for electro-optical application[7]. This may be attributed to a multi-twisting power in Sm*CChLCPC. When a small amount of Sm*CLC is added to ChLCPC, we think, there may exist a complex texture of a chiral smectic structure and a cholesteric structure called a multi-twisting power texture, which will increase the turbidity or contrast ratio of LCPC. Improvement of the response time may be attributed to the lower twisting power due to a chiral smectic structure. So one can see that the newly developed Sm*CChLCPC has a very low driving voltage, high contrast ratio and also quick response time both of τ_r and τ_d, which reveals that the multi-twisting power introduced

TABLE 1 Components of Sm*CChLCPC and ChLCPC

Materials	Name	Sm*CChLCPC	ChLCPC
NeLCs	4-cyano-4'-pentyl biphenyl	89.6%	89.6%
ChLCs	Cholesteric acetate	0.2%	0.4%
Sm*CLCs	LIXON-CS 2003 (Chisso Co., Tokyo)	0.2%	----
Polymer	Poly(methyl-methacrylate)	10.0%	10.0%

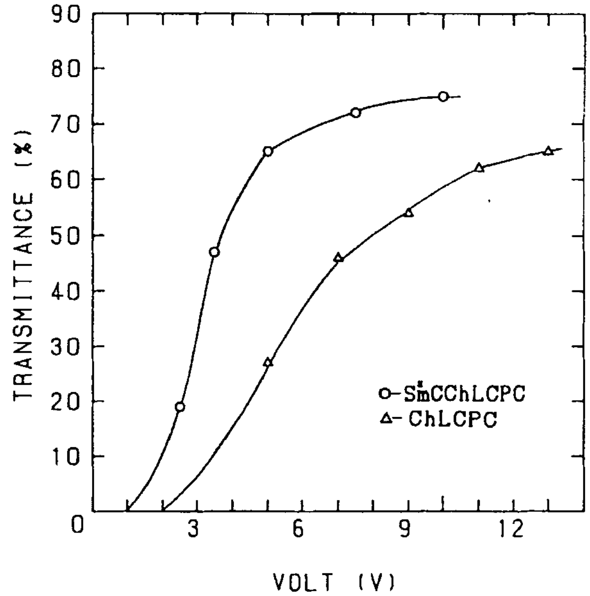

FIGURE 1 (a) Difference of transmittance between Sm*CChLCPC and ChLCPC with the voltage at 500Hz.

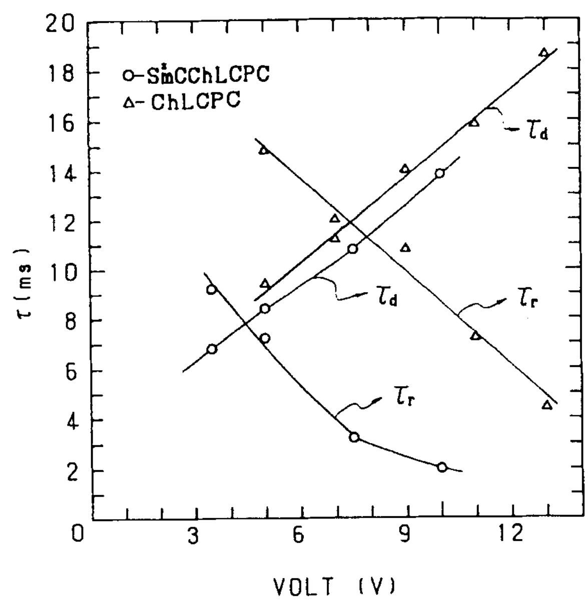

FIGURE 1 (b) Difference of response time between Sm*CChLCPC and ChLCPC with the voltage at 500Hz.

in LCPC is a very important effect on electro-optical properties of LCPC.

POLYMER WALL EFFECT ON ELECTRO-OPTICS OF LCPC

Polymer wall effect is considered to depend on polymer's physical properties, for example, anchoring acceptability, concentration of polymer and sample's thickness. Different polymers will cause different turbidity of LCPC mainly depending on the formation of cholesteric polydomain textures in polymers. In our research, the best polymer was firstly selected according to the turbidity of LCPC, and then the effects of polymer concentration and the sample's thickness on electro-optical properties of LCPC were investigated. Fig.2 shows the transmittance and the response time of LCPC with different polymer concentration against voltage at 500 Hz. It could be seen from Fig.2 that the response time especially τ_d is greatly shortened with increasing the polymer concentration, which reveals that with increasing the concentration of polymer the polymer wall effect acts most effectively for quick recovery response time. However, the increased polymer would cause much higher threshold-voltage for transmittance. When the polymer concentration was increased above 20%, the transmittance of LCPC films would be greatly reduced because the polydomain LC grains for scattering light in LCPC films were decreased.

Fig. 3 shows the effect of sample's thickness on the electro-optics of LCPC. The results show that the effect of the thickness on the electro-optics of LCPC is much complicated. The thicker the sample, the higher the transmittance of LCPC in the same E (KV/cm), which reveals that for thicker sample, polymer would cover the polydomain LC grains more effectively so as to get higher contrast ratio. Also, one could see from the Fig.3 that for different thickness, the τ_r of LCPC films is almost the same at the same E (KV/cm), but the τ_d of them is quite different. The thicker the sample, the shorter the τ_d with E (KV/cm), which presents

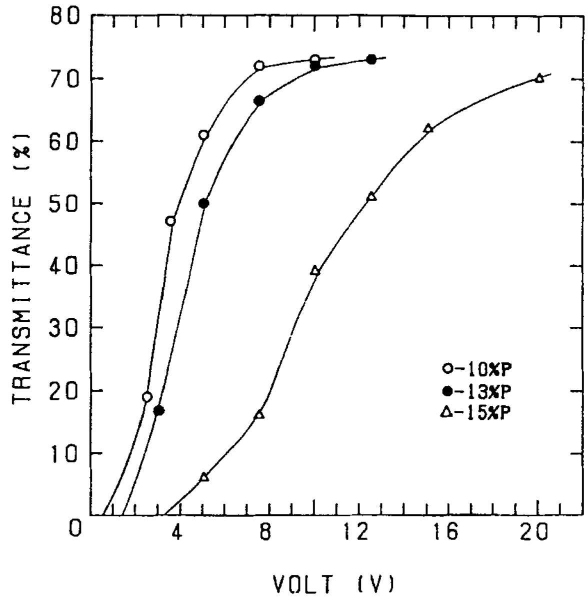

FIGURE 2 (a) Effect of polymer concentration on the transmittance of LCPC with voltage at 500Hz.

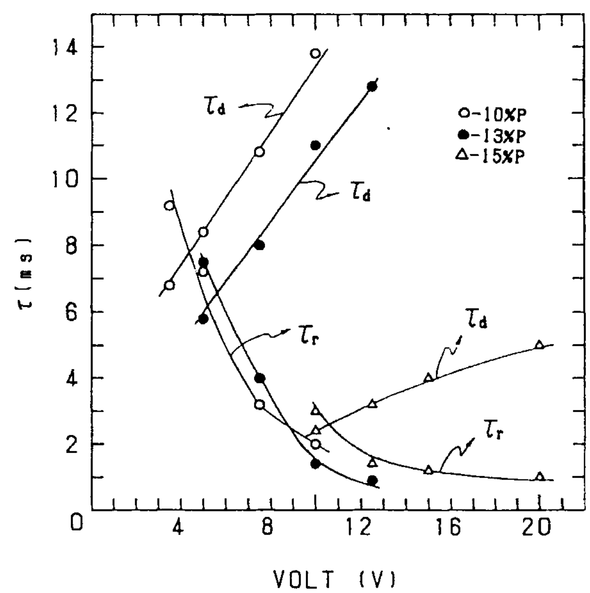

FIGURE 2 (b) Effect of polymer concentration on the response time of LCPC with voltage at 500Hz.

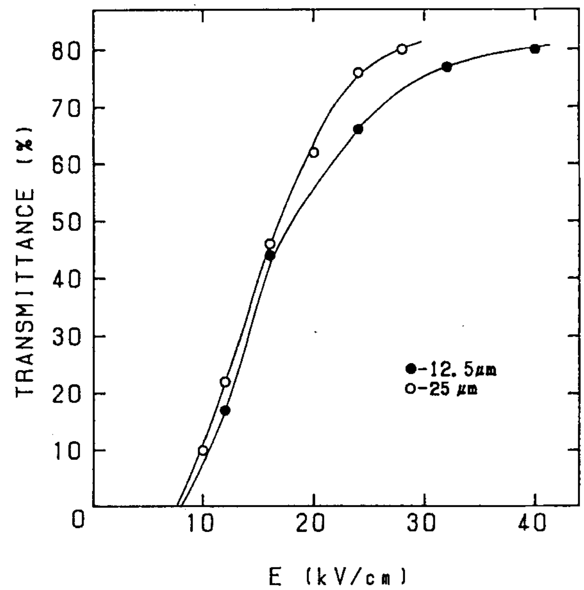

FIGURE 3 (a) Effect of sample's thickness on the transmittance of LCPC with voltage at 500Hz.

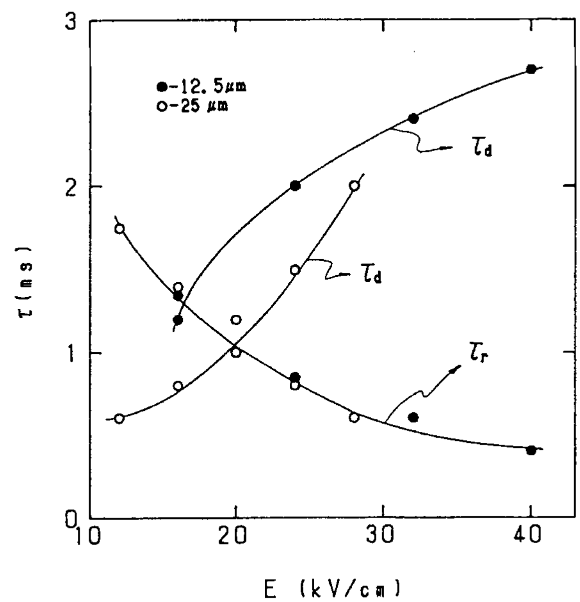

FIGURE 3 (b) Effect of sample's thickness on the response time of LCPC with voltage at 500Hz.

that polymer wall effect is much better for thicker samples. The polymer wall effect on τ_d will be discussed below.

THE INTERPRETATION FOR POLYMER WALL EFFECT IN LCPC

It was found that the polymer wall mainly affected on the recovery time (τ_d) of LCPC from ON state when switched OFF, which reminded us of a question, what was the reason for polymer wall much affected on the decay time? It is well known that the response time, especially decay time of low molecular liquid crystals is a little long, however why the decay time will be greatly reduced when blended with polymers? Some people have tried to explain the polymer wall effect[8]. Here we have other explanations. For low molecular weight liquid crystals (LMLCs), there exists a liquid effect (micro-flow effect), when switched OFF from electricity the orientated molecules will gradually return to the original state via the turbulent motion of liquid crystal molecules[9], so the $_d$ would be little long. However, in LCPC, there is no such a liquid effect because the polymer covers finely the polydomains of liquid crystals. So when switched OFF the orientated LC molecule in LCPC will quickly return to the original scattering state. Fig.4 is the model of the recovery from ON state of LMLCs and LCPC.

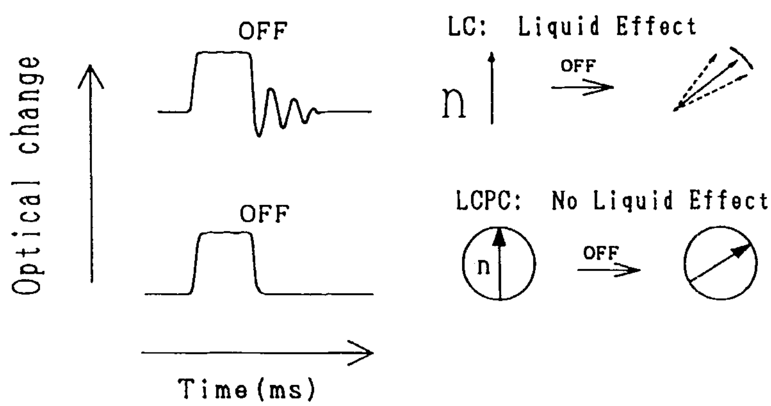

FIGURE 4 Model of electro-optical relaxation of LCs and LCPC from ON state when switched OFF.

The liquid-micro-flow effect of LMLCs can also be fixed by using bias voltage instead of polymer wall to get a quick recovery. Fig.5 shows the different recovery picture of LMLCs' texture from ON state when switched OFF. The unclear picture (a) shows the liquid-micro-flow and a long relaxation time when switched OFF from 15 Volt to 0 Volt. The clear picture (b) shows a very short relaxation time when switched OFF from 20 Volt to 5 Volt. Here 5 bias Voltage could fix the liquid-flow effect and did the same as the polymer wall. Therefore, it is clear that the polymer wall effect in LCPC is to cover the LMLCs' grains and fix the liquid effect of LMLCs so as to get a very quick response and a good contrast ratio for electro-optics.

FIGURE 5 (a) Recovery texture of LMLCs from ON state when switched OFF from 15 volt to 0 volt. See Color Plate I.

FIGURE 5 (b) Recovery texture of LMLCs from ON state when switched OFF from 20 volt to 5 volt. See Color Plate I.

CONCLUSIONS

A new kind of liquid crystals and polymer complex (LCPC) with multi-cholesteric focal conic polydomain textures was developed. This LCPC film has a very low driving voltage, very quick response time and also high contrast ratio for electro-optical application. The electro-optical properties of LCPC are greatly affected by twisting power of cholesteric liquid crystals and polymer wall effect. Therefore, one can develop various kinds of LCPC films which have different driving voltage, response time and contrast for light shutter and display applications by controlling polydomain textures of LCs and polymer wall effect in LCPC's films. Besides, it was found that the temperature before polymerization would greatly affect the turbidity of LCPC films after polymerization, which will be reported in near future.

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