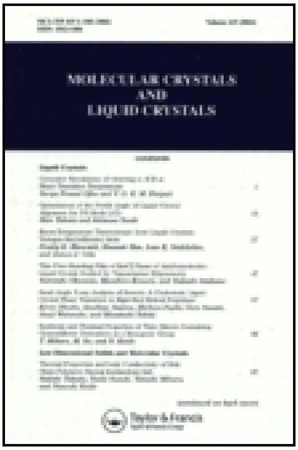

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Helically Aligned Holographic Polymer Dispersed Liquid Crystal (HPDLC)

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The diffraction characteristics of a new type of alignment-controlled holographic polymer dispersed liquid crystal (AC-HPDLC) were studied. A very fine, 100-nm-scale, polymer region was formed holographically by keeping the LC helically aligned. The polarization dependence of ordinary AC-HPDLC was reduced due to the axial symmetry of the alignment. The induced modulation in the refractive index of the HPDLC when an electric field is applied interferes with the reflection of the helical structure. This coexistence of controlled and natural structures should achieve materials with higher functionality.

Keywords: Hologram; Helical alignment; Chiral nematic; LC-monomer HPDLC

INTRODUCTION

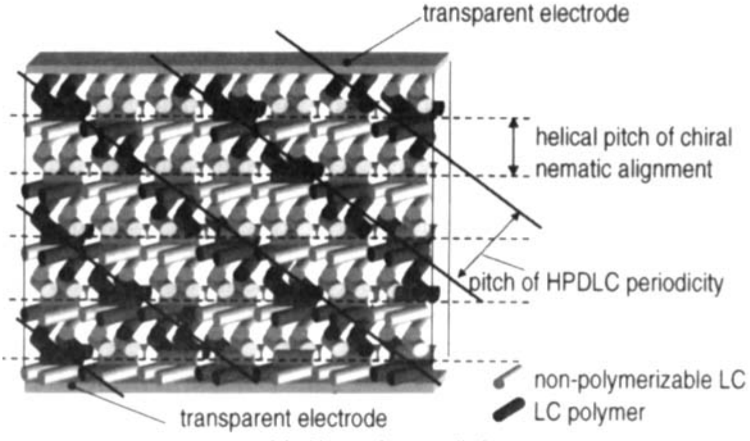
The need to reduce the power consumption of portable information devices has led to the study of reflective displays, which use the ambient light as illumination. Our group considered it especially promising to fabricate an electrically switchable multi-layer dielectric film using liquid crystal (LC) and polymer and to use the interferential reflection, which ideally can be operated without loss. We therefore proposed the use of holographic polymer dispersed liquid crystal (HPDLC) for reflective color displays [1].

The HPDLC is based on PDLC [2,3], an electrically switchable optical diffuser. By improving one of the methods to fabricate PDLC, the photo-polymerization induced by phase separation (PPIPS) [4], electrically switchable diffractive optics have been fabricated holographically and studied [5-9]. To apply HPDLC to reflective displays, a finer structure consisting of almost 100-nm-thick LC droplets and polymer layers was fabricated [1,10]. However, the reflection spectral width was so narrow that the total reflection efficiency was too low. Alignment control is effective to widen the width [11]. Therefore homogeneously aligned AC-HPDLC [12,13,14] using LC-monomer, which is based on reverse-mode PDLC [15], was fabricated. The alignment control also helped reduce the unexpected scattering. To reduce the polarization dependence and improve the optical functionality, we have now fabricated a more highly structured composite material.

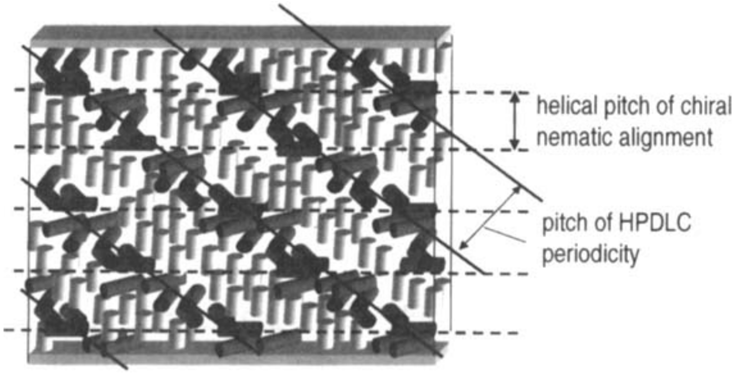
EXPERIMENTS AND RESULTS

Target structure

Figure 1 shows the structure of our new helically aligned HPDLC material. It consists of a composite of LC and LC-polymer. Initially, when no voltage is applied (Figure 1(a)), the LC molecules are aligned helically, the same as they are in the chiral nematic (N*) phase. There are periodic polymerized and non-polymerized regions, the same as in HPDLC reflective display devices [12]. In this state, there is a wavelength-selective reflection for circularly polarized light due to the helical alignment. When voltage is applied (Figure 1(b)), the non-polymerizable LC molecules rotate toward the electric field, while the LC-polymer molecules do not. Periodic modulation in the refractive index is thus generated that corresponds to the polymerized region. There is selective diffraction based on the Bragg condition, the same as in alignment-controlled (reverse-mode) HPDLC. Because helical structure is disordered partly, the reflection based on helix decreases.



(a) with no voltage applied



(b) with voltage applied

Figure 1 Structure of helically aligned HPDLC material.

Sample preparation

We used methyl-substituted 1,4-phenylene bis {4-(6-(acryloxy) hexyloxy) benzoate} [16] as the liquid-crystalline monomer (Figure 2) and TMPTA (2-ethyl-2-(hydroxymethyl)-1,3-propanediol triacrylate) as the non-LC multi-functional monomer to make the polymer region rigid. A mixture of LC and non-LC monomers, LC (ML-1009, Merck), chiral dopant (S-1011, Merck), and a little photo initiator was placed in a glass cell with an anti-parallel alignment layer made of rubbed polyimide. The cell gap was 5 μm. The composition ratio (in weight) was LC-monomer:non-LC-monomer:LC:chiral-dopant 14:3:(83-x):x. The concentration of chiral dopant (x) was a variable, while the ratio of polymerizable material to non-polymerizable material was fixed. The interferential fringes of the laser beam (488 nm) from a single-frequency argon ion laser (Innova 308, coherent) were irradiated onto the cell (Figure 3). The interferential fringes were tilted, the same as for transmission-type HPDLC used in reflective displays [14]. The laser irradiation formed a polymer network periodically corresponding to the interferential fringes because the polymerization occurred at the fringe peaks.

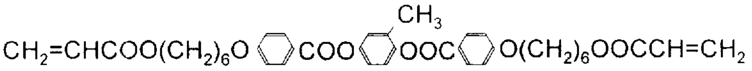


Figure 2 Molecular structure of liquid-crystalline monomer. Its phase series is K86N116I [16].

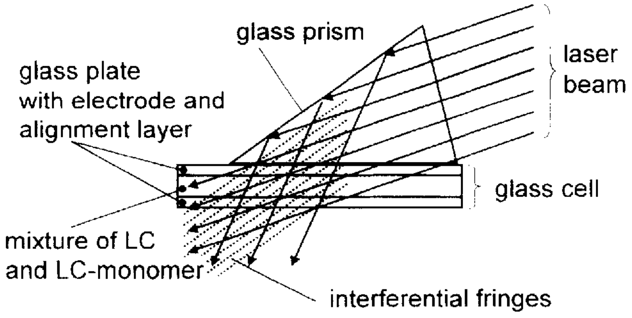


Figure 3 Optical setup to fabricate helically aligned HPDLC; cell gap: 5 μm, anti-parallel alignment.

Results

We evaluated the fabricated structures by measuring the transmission spectra for polarized light. The incident angle was normal to the sample.

Figure 4 show the transmission spectra of a sample in which no chiral material was doped. This HPDLC had strong polarization dependence. The light polarized parallel to the alignment was well diffracted.

Figure 5 shows the transmission spectra of the sample in which 4.0% chiral material was doped, with and without an applied voltage for two linearly polarized illuminations. With no voltage applied, the sample was transparent for visible wavelengths. When an electric field was applied, a dip corresponding to the diffraction was observed. As shown in this figure, the polarization dependence of AC-HPDLC was reduced. As shown in Figure 6, under circularly polarized illumination, there was slight polarization dependence due to the helical alignment.

Figure 7 shows the transmission spectra of a sample whose reflection of the helical structure is in visible wavelengths. When voltage was applied, though reflection from the helix was reduced due to disorder, HPDLC reflection was induced.

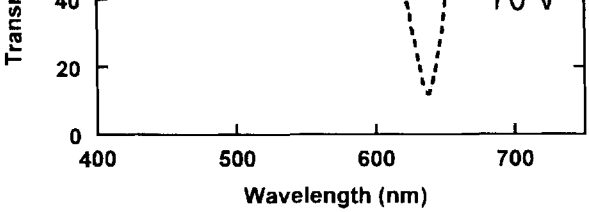


Figure 4 Transmission spectra for linearly polarized light passing through a sample in which chiral-dopant concentration x was 0. Solid lines represent spectra for light polarized perpendicular to the alignment. Dashed lines show that for light polarized parallel to the alignment.

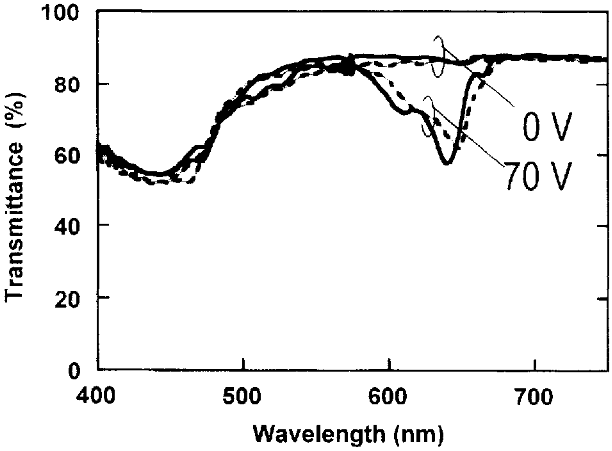


Figure 5 Transmission spectra for linearly polarized light passing through a sample in which chiral-dopant concentration x was 4.0. Solid lines represent spectra for light polarized perpendicular to the alignment. Dashed lines show that for light polarized parallel to the alignment.

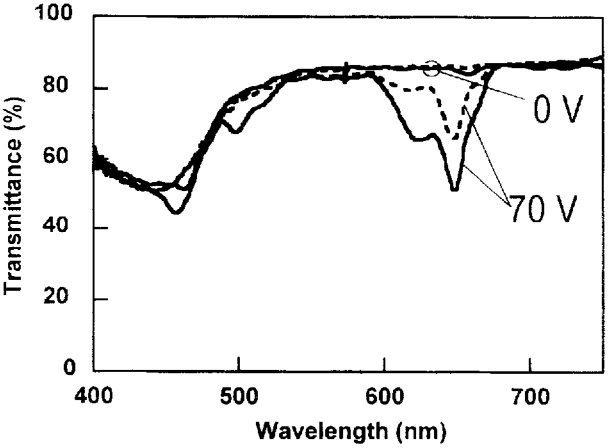


Figure 6 Transmission spectra for circularly polarized light passing through a sample in which chiral-dopant concentration x was 4.0. Solid lines represent spectra for a polarized light, the same as that of helical alignment reflection. Dashed lines show that for the oppositely polarized light.

CONCLUSION

We have demonstrated the fusion of a self-organized helical structure and a controlled periodical structure in a composite polymer/LC material. Its helical structure reduced the polarization dependence of AC-HPDLC because of the axial symmetry of the helical structure. Induction of refractive index modulation due to the controlled periodic structure interfered with the reflection of the helix. Though the contrast was very low in this experiment, it suggests that the existence of a new mechanism that switches the cholesteric reflection. This coexistence of controlled and natural fine structures should achieve materials with higher optical functionality.

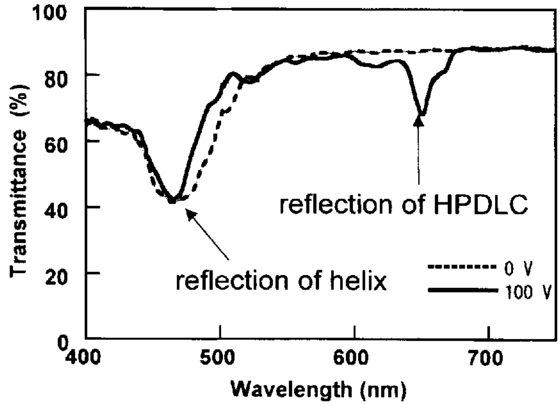


Figure 7 Transmission spectra of light passing through a sample in which chiral-dopant concentration x was 8.3.

References

[1] K. Tanaka, K. Kato, S. Tsuru, and S. Sakai, *J. SID*, **2**, 37 (1994).
[2] J.L. Fergason, *SID Int. Symp. Dig. Tech. Papers*, **16**, 68 (1985).
[3] J.W. Doane, A. Golemme, J.L. West, J.B. Whitehead, Jr., and B.-G. Wu, *Mol. Cryst. Liq. Crest.*, **165**, 511 (1988).
[4] N.A. Vaz, G.W. Smith, and G.P. Montgomery, Jr., *Liq. Cryst.*, **146**, 1 (1987).
[5] J.D. Margerum et al., *U.S. Patent*, 4, 938, 568 (1988).
[6] R.L. Sutherland, *SPIE*, **1080**, 83 (1989).
[7] R.L. Sutherland, L.V. Natarajan, and V.P. Tondiglia, *Chem. Mater.*, **5**, 1533 (1993).
[8] R.L. Sutherland, L.V. Natrajan, and V.P. Tondiglia, *SPIE*, **2152**, 303 (1994).
[9] Y. Fuh, C.Y. Huang, M.-S. Tsai, J.-M. Chien, and L.-C. Chien, *Jpn. J. of Appl. Phys.*, **35**, 630 (1996).
[10] M. Date, Y. Takeuchi, K. Tanaka, and K. Kato, *J. SID*, **7**, 17 (1999).

[11] M. Date, Y. Takeuchi, K. Tanaka, and K. Kato, *IEICE Trans. on Elec.*, **E81-C**, 1685 (1998).
[12] K. Kato, T. Hisaki, and M. Date, *Jpn. J. Appl. Phys.*, **38**, 805 (1999).
[13] K. Kato, T. Hisaki, and M. Date, *Jpn. J. Appl. Phys.*, **38**, 1466 (1999).
[14] M. Date and T. Hisaki, *6th Int. Display. Workshop (IDW'99)*, 101 (1999).
[15] R. Yamaguchi, Y. Waki, and S. Sato, *Jpn. J. Appl. Phys.*, **36**, 2771 (1997).
[16] D.J. Broer, R.A.M. Hikmet, and G. Challa, *Makromol. Chem.*, **190**, 3201 (1989).