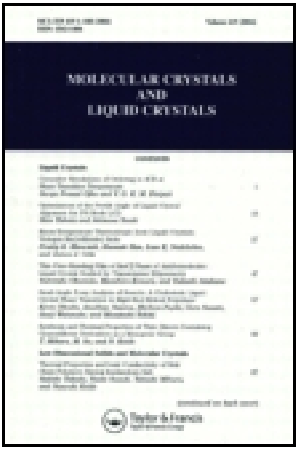

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Diffraction Efficiency Improvement in Holograhic Polymer Dispersed Liquid Crystal (HPDLC) Devices

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Holographic Polymer Dispersed Liquid Crystals (HPDLC) devices are potentially useful for color reflective type LCDs. In our experiments, HPDLC devices were made from a mixture of LC and light-curable resin containing an oligomer and were formed by laser interference exposure. In order to obtain highly diffracted intensity, we first investigated the dependence of diffraction efficiency in HPDLC devices on laser intensity and the relationship between the phase separation temperature of the mixture and diffraction efficiency. The phase separation temperature of the mixture can be tuned to the oligomer ratio of the light-curable resin. We found that the diffracted intensity increased as laser intensity increased, and also as the phase separation temperature of the mixture increased.

Keywords: HPDLC; phase separation temperature

INTRODUCTION

While color reflective type LCDs are particularly attractive for their low power consumption, conventional designs have a serious drawback in term of image brightness because their polarizers and color filters reduce light efficiency, and reflective LCDs without those two elements would seem to offer a significant improvement in brightness. That is why have chosen to work with HPDLC devices.

HPDLC devices are constructed of alternating layers of LC droplets and light cured resin. This gives them Bragg diffraction characteristics. The structure is produced by a photo-polymerization induced phase separation (PIPS) process under laser interference exposure[1-3]. HPDLC device performance depends on this PIPS process. In order to obtain high diffraction devices, we first investigated the dependence of diffraction efficiency on laser intensity and on phase separation temperature.

EXPERIMENTAL

In our experiments, we employed liquid crystal (BL-036, Merck) and visible light-curable resin (LUX0208, Toagosei) / oligomer mixture. The polymerization of the light-curable resin was initiated by blue light (e.g., Ar ion laser at a wavelength of λ = 488 nm). We maintained an LC ratio of 30wt% throughout the experiments. The materials were mixed together at room temperature until homogeneous. As shown in Table 1, we adjusted the phase separation temperature of the mixture to the oligomer ratio of the light-curable resin. The mixture was then sandwiched between indium-tin-oxide (ITO) coated glass slides separated by a 25 μm thick spacer.

Table 1. Composition of light-curable resin materials and phase separation temperature (PST) of mixture.

	M0	M1	M3	M5	M7
LUX0208 / Oligomer	100/0	90/10	70/30	50/50	30/70
PST (℃)	<-25	<-25	<-25	-6	13

Using an Ar ion laser beam (50mW/cm^2), we formed polymer dispersed liquid crystals devices from the mixtures indicated in Table 1 (M0～M7). The laser beam dose was fixed at 6 J/cm^2. As shown in Figure 1, the transmittance of these devices decreased as the oligomer ratio increased, as a result of an increase in scattering intensity. Degree of scattering intensity depended on the density of the LC droplets. We then examined the structure of the PDLC devices with a polarizing microscope (Figure 2). As shown in Figure2, the size of LC droplets was independent of the oligomer ratio. That is to say, transmittance spectra resulted from differences in the density of LC droplets.

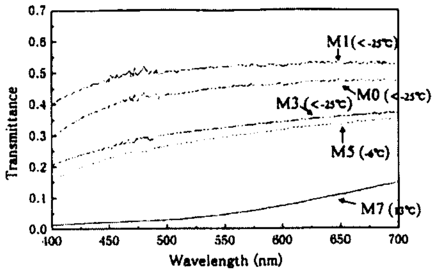
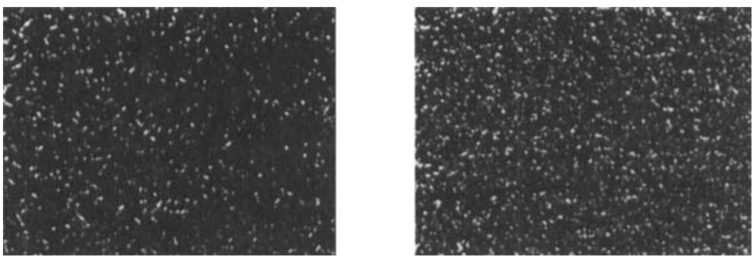


Figure 1. Transmittance spectra of PDLC devices



(a) (b)

Figure 2. Micrographs of PDLC devices using (a) M0 and (b) M7

We used the two beams from an Ar ion laser, intersected at an angle of 90 degrees, to fabricate HPDLC devices (see Figure 3). The two beams had been expanded to a diameter of ～10 mm, and their intensities were kept equal with experiments being conducted over a range of 5～100 mW/cm^2. Cells were set at a 35-degree tilt to the incident light. The resulting pitch of the multilayer structure was about 180nm, and after this interference exposure, the structure had a peak wavelength of about 540nm.

RESULTS AND DISCUSSION

Dependence of diffraction efficiency on laser intensity for HPDLC devices

We measured the transmittance spectra of the HPDLC devices in order to investigate the dependence of diffraction efficiency on laser intensity. As shown in Figure 4, the transmittance spectra show sharp dips resulting from the alternating-layer structure, and also exhibit the scattering characteristics. As the figure also shows, transmittance increased with increase in wavelength. For our experiments, we defined diffraction intensity as the depth of the dip shown in Figure 4. We express it here, as may be seen in Figure 6, as percentage of total depth A.

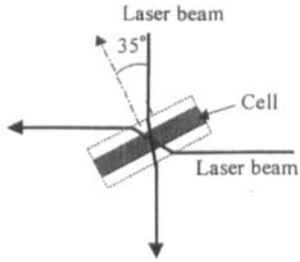


Figure 3. The optical system in this experiment

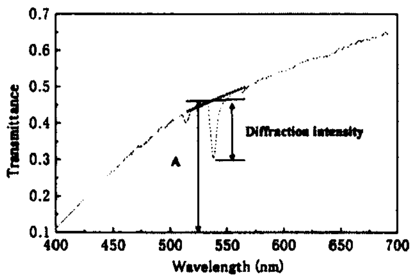


Figure 4. Normalized diffraction intensity

The data shown in Figure 5 are for mixture M7. HPDLC devices were formed with five different laser beam intensities, 5mW/cm^2, 10 mW/cm^2, 25mW/cm^2, 50mW/cm^2 and 100mW/cm^2, at a fixed laser beam dose of 6 J/cm^2.

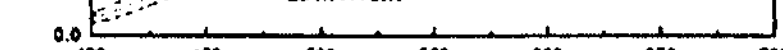


Figure 5. Transmittance spectra of HPDLC devices

After holographic exposure, the transmittance spectra of the HPDLC devices were measured (see Figure 5). The normalized diffraction intensities for the 5 samples are plotted in Figure 6. As may be seen, by comparing Figure 5 and 6, the resulting dip wavelengths agree with Bragg's law, and normalized diffraction intensity increases as laser beam intensity increases. We also found that transmittance spectra increases as laser beam intensity increases. The difference of transmittance results from the scattering characteristics, which might be expected to depend on LC droplet size, on LC droplet intensity, or on both. As applied here to the same mixture, however, variations in laser beam intensity can be expected to result in differences in droplet size but not in overall droplet density. That is to say, here the differences in droplet size : higher laser intensities produce smaller LC droplets, which leads to higher transmittance and higher diffracted intensities.

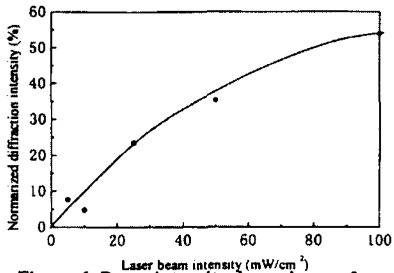


Figure 6. Beam intensity dependence of HPDLC devices

<u>Dependence of phase separation temperature of the mixture</u>

For the purpose of investigating the relationship between the phase separation temperature of the mixture and the diffraction efficiency of HPDLC devices, we fabricated HPDLC devices corresponding to the five mixtures in Table 1. Laser beam intensity and laser dose were fixed at 50mW/cm^2 and 6 J/cm^2, respectively. After holographic exposure, we measured their transmittance spectra (see Figure 7), and plotted their normalized diffraction intensity (see Figure 8). As shown in Figure 7, transmittance spectra increased as the oligomer ratio decreased. Since LC droplet size is independent of the oligomer ratio, as shown in Figure 2,

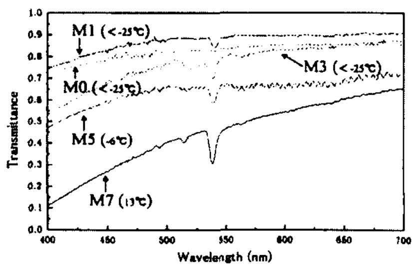


Figure 7. Transmittance spectra of HPDLC devices

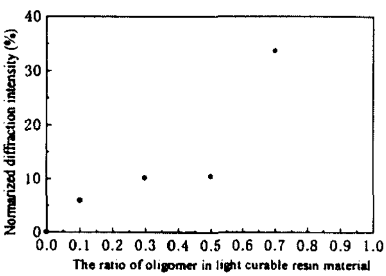


Figure 8. Oligomer ratio dependence of Diffraction intensity

however, it must be that LC droplet density decrease with decreases in the oligomer ratio. We also found that each dip stayed at the same wavelength without regard to the oligomer ratio of the mixture. Our results also show that the diffracted intensity of HPDLC increases as the oligomer ratio in the mixture increases (Figure 8), which indicates an increased density of LC droplets and significant refractive index modulation in the HPDLC.

CONCLUSION

We have investigated the dependence of diffraction efficiency in HPDLC devices on laser intensity and on phase separation temperature, which can be adjusted to the oligomer ratio in a light-curable resin. Our results show that a higher laser intensity reduces LC droplet size and produce the higher diffraction efficiency and higher transmission spectra. They also show that the diffraction intensity of HPDLC devices increases as the oligomer ratio increase, which indicates an increased density of LC droplets and significant refractive index modulation. That is to say, increases in intensity and in oligomer ratio can be used to improve diffraction intensity.

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