Title	Application of Siloxane-containing Liquid Crystals to Holographic Polymer-dispersed Liquid Crystal Grating Formation
Author(s)	何, 曼
Citation	
Issue Date	2005-09
Type	Thesis or Dissertation
Text version	none
URL	http://hdl.handle.net/10119/2187
Rights	
Description	Supervisor:川上　雄資, 材料科学研究科, 博士

Application of Siloxane-containing Liquid Crystals to Holographic Polymer-dispersed Liquid Crystal Grating Formation

HE Man (240202) KAWAKAMI Lab

Background

Data storage and management fuels many aspects of the world's economy. Holographic Data storage has been one of the bright spots in technology over the past decades. The main advantages of holographic storage---high density and speed---come, from three-dimensional recording and from the simultaneous readout of an entire page of data at one time (as shown in Figure 1.1). Uniquely, holographic memories store each bit as an interference pattern throughout the entire volume of the medium [1].

Holographic Polymer-Dispersed Liquid Crystal(HPDLC) are efficient materials for holographic storage, because they provide a simple, fast and solvent free recording process[2-4]. One of the most important properties of HPDLC gratings is that they can be electrically switched across the final film by electrically controlling the orientation of the LC located between the polymer layers. Fine gratings with high diffraction efficiency can be achieved through the efficient modulation of the refractive index, which is caused by the difference in modulation between the LC and the polymer.

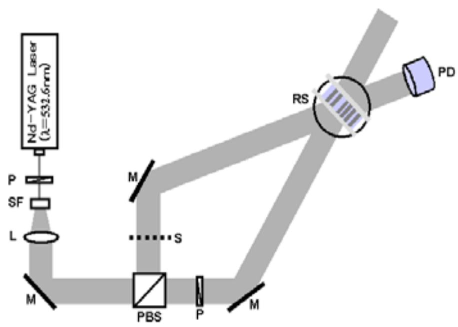
However, control of refractive index modulation presents a number of problems: volume shrinkage is caused by the change in chemical bond length during the polymerization, moreover, poor phase separation leaves much of the LC in polymer, thus, decreasing refractive index modulation[5,6].

Objective

To overcome this difficulty (poor phase separation), I will attempt to improve the HPDLC gratings formation by introducing siloxane chain into phase separation. Basis on hologram writing techniques, in this work, however, I have concentrated on the effect of the siloxane-containing liquid crystal (SLC)on grating formation. The goal of a second important line of research is to find out a suitable polymerization system for the phase separation of SLC and to establish a relationship between the monomer functionality and the phase-separated morphology in the SLC based HPDLC system.

Experimental

Holographic transmission gratings were formed by coherent two beams of Nd-YAG laser (λ=532.6nm) (Coherent Inc., Verdi-V2) of equal intensity with a true power of 30mW/cm^2. The beams were collimated and expanded by spatial filters and lens. Experimental setup is shown in **Figure 1**(right).



Results and discussion

High contrast grating with high diffractive efficiency was attained, which suggested that the environment stability and flexible character of siloxane chain might play unequal role in phase separation.

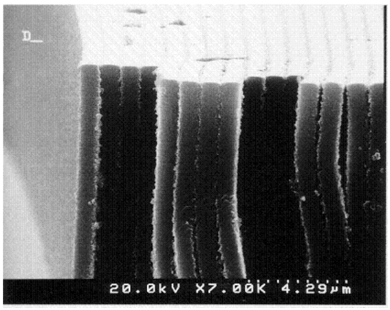


Figure 2

HPDLC Grating with diffraction efficiency(DE) 40% could be formed with 10wt% SLC (CBS3) based on a multi-acrylate polymer system (5f:NVP=4:6). The typical HPDLC layer structure indicated the effective phase separation process. As shown in **Figure 2**

Changes the polymerization monomer and photoinitator also have found significant effect on the phase separation (**Table 1** and **Figure 3** (read line)). The ring-opening monomer and KC/DPI were found efficient on the grating formation.

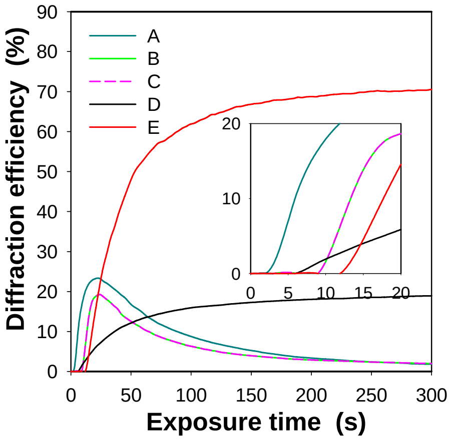


Figure 3

Table 1	Matrix	PS/PI (0.4wt%/3wt%)	DE (%)
A	**5F** : **2F** : **NVP** = 4 : 5 : 1	**RB**/**NPG**	2
B	**5F** : **2F** : **NVP** = 4 : 5 : 1	**KC**/**DPI**	2
C	**5F** : **2F** : **BGE** = 4 : 5 : 1	**KC**/**DPI**	2
D	**5F** : **N2R** : **BGE** = 4 : 5 : 1	**RB**/**NPG**	18
E	**5F** : **N2R** : **BGE** = 4 : 5 : 1	**KC**/**DPI**	70

Moreover, significant difference in grating morphology was observed between gratings made with control LC (5CB and 8CB) and SLC, as show in **Figure 4**.

The 5CB (or8CB) could not phase separated well caused a poor grating morphology and low diffraction efficiency. The coarse and irregular interface between LC channel and polymer strongly indicated the unsatisfied phase separation (**Figure 4** (a) SLC and (b) 5CB).

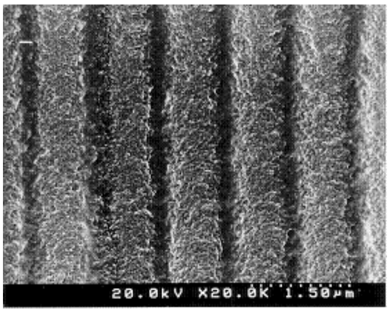


Figure4 (a) SLC 10wt%

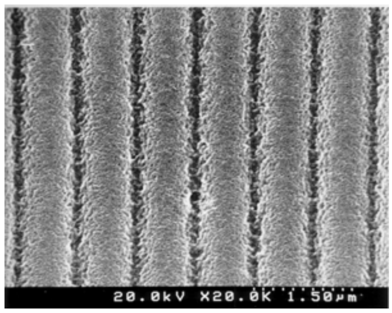


Figure 4.(b) 5CB 10wt%

Table 2	**5F** : **N2R** : **BGE**	DE (%)
A	4 : 3 : 3	26
B	4 : 4 : 2	49
C	4 : 5 : 1	70
D	4 : 6 : 0	60

Meanwhile, the diluent BGE shown strongly effect on grating formation, as evidenced by the change of diffraction effieciency(DE) of the final gratings. As shown in **Table 2, 5F:N2R:BGE=4:5:1 gave out the highest DE.**

Table 3	SLC (10wt%)	DE (%)
A	9OS2CB	68
B	11OS3CB	70
C	9OS2BE	73
D	11OS3BE	78
E	5CB	35

All synthesized SLC with varying siloxane chain spacer and mesogen were found create an efficient phase separation, as evidenced by the high diffraction efficiency (DE). This result strongly indicated that the increased chemical incompatibility and the flexible character of siloxane spacer must play a main important role during the phase separation of SLC by lowing the requirement of driving force and enhance the mobility of the SLC (**Table 3**)

No significant change in DE was found when we changed the irradiation power, but the real time study indicated that high irradiation power accelerated the primary stage of the polymerization. The best irradiation power level is around 15mW/cm^2, and under such conditions we can obtain a fine grating with high DE of 70%, even the exposure time is as short as 100 second. The balance between the gelation time and the diffusion time was confirmed has effect on the grating phase separation (**Figure 5**).

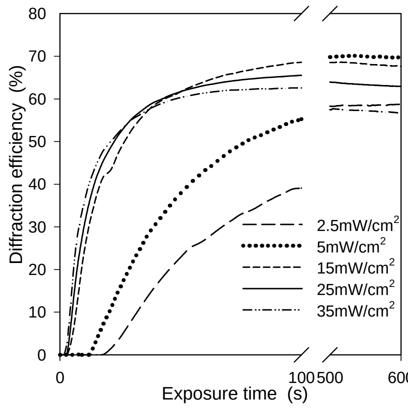


Figure 5

In this study, it was found that introduce of siloxane-containing compounds into holographic system made great changes in the phase separation, according to the stranger diffusion capability of siloxane spacer, and the strong chemical incompatibility between siloxane chain and polymer. A fine grating with 70% diffraction efficiency was formed with 4'-{6-(heptamethyltrisiloxan-1-yl)hexyloxy}-4-cyanobiphenyl as low as 10wt%. The efficiency was even higher than that of a grating prepared with commercial 4'pentyl-4-cyanobiphenyl or 4'octyl-4-cyanobiphenyl as the liquid crystal component.

A combination of radically and ring-opening polymerizable cross-linking multi-functional monomers (acrylate/expoxide based photo-polymerization system) produced a low density polymer, controllable plymerization rate and prolong the diffusion time of the SLC, gave the gratings with high diffraction efficiency and long term stability.

References

1. L.d'Auria, J.P. Huignard, C. Slezak, and E. Spitz, "Experimental holographic read-write memory using 3-D storage," Appl. Opt. *13*, 808-818 (**1974**).
2. R.L. Sutherland, L.V. Natarajan, V.P. Tondiglia, and T.J. Bunning, Chem. Mater. *5*, 1533 (**1993**).
3. C.F. van Nostrum, R.J. M. Nolte, D.J. Broer, T. Fuhrman, and J. H. Wendorff, Chem. Mater., 10p.135 (**1998**); OPTIMAS 6 (Optimas Corporation, Bothell, Washington).
4. C. Serbutoviez, J. G. Kloosterboer, H.M. J. Boots, and F. J. Touwslager, Macromolecules *29*, 7690 (**1996**).
5. R.T. Pogue, L.V. Natarajan, S.A. Siwecki, V.P. Tondiglia, R.L. Sutherland, T.J. Bunning. Polymer *41* (**2000**) 733-741; Timothy J. Bunning. Chem. Mater. **2003**, *15*, 2477-2484.
6. Schulte MD, Clarson SJ, Natarajan LV, Tomlin DW, Bunning T.J. Mol Cryst Liq Cryst **2002**; *373*, 155-80.