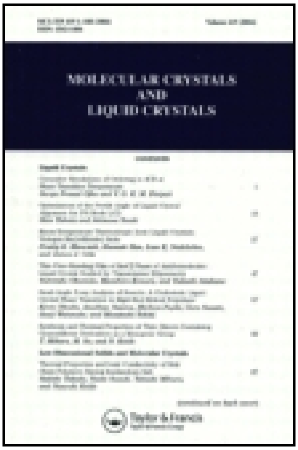

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

High Sensitive and Efficient Holographic Grating Generation in Functionalized Polymer-Dissolved Liquid Crystal Composites

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Version of record first published: 24 Sep 2006

Mol. Cryst. and Liq. Cryst., 2001, Vol. 368, pp. 319-325
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High sensitive and efficient holographic gratings were generated in functionalized polymer-dissolved liquid crystal composites. The gratings originate in the photorefractive-like space charge filed and resultant periodic reorientation of liquid crystal molecules. The demonstration for edge-enhancement of two-dimensional optical images was performed by using the developed materials.

Keywords: photorefractive effect; liquid crystal; hologram; edge-enhancement; polymer

1. INTRODUCTION

Photorefractive mesogenic materials represent the newest class of photorefractive materials. Rapid advances in the field of photorefractive mesogenic materials in the brief time since their inception in 1994 [1] led to the development of high performance [1-18]. Photorefractive mesogenic materials show high-performance due to high birefringence and ease of fabrication, therefore, achieve high-sensitivity under low applied voltage. From considering the morphology, the photorefractive mesogenic materials are divided into three classes, i.e. (1) dye-doped low-molar-mass liquid crystals (L-LCs) [1-5, 13], (2) polymer dispersed liquid crystals (PDLCs) [6, 7, 9, 12-14], and (3) polymer dissolved liquid crystals (PDLCCs) [8, 15-18]. Among them, photorefractive PDLCCs have the following advantages: operating voltage low enough for high diffraction efficiencies, high resolution, and ease of fabrication of homeotropic alignment with a large area. The photorefractive PDLCCs consists of low-molar-mass liquid crystals, polymer and photoconductive agents, in which all components are miscible and phase separation is not occurred. In this paper, we present photorefractive PDLCCs containing the functionalized copolymer and the application in the field of optical information processing is demonstrated.

2. MATERIALS

One of the merits of photorefractive PDLCCs is the use of a highly functionalized polymer. Our photorefractive PDLCCs described here are based on the functionalized copolymer as shown in Figure 1, a nematic L-LC mixture with 4-cyanobiphenyl E7, and TNF as a photoconductive sensitizer.

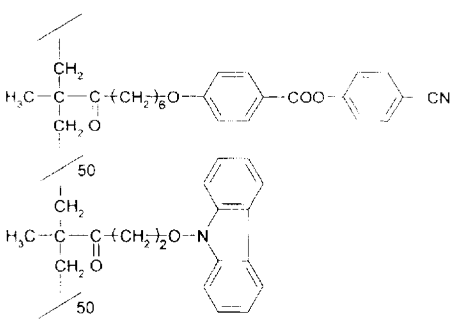

FIGURE 1 Chemical structure of functionlized copolymer for photorefractive PDLCCs.

We incorporated the 4-cyanobenzoate group, which is also contained in E7, into the copolymer side-chain. Since the chemical structure of the 4-syanobenzoate group resembles that of E7, E7 dissolves copolymer as described in Figure 1 and phase-separation in the scale of visible wavelengths dose not occur, which is preferable to reduce the light scattering losses in the holographic media. Polymer also plays another important role in maintaining the homeotropic alignment of PDLCCs sandwiched between one pair of ITO coated glass substrates.

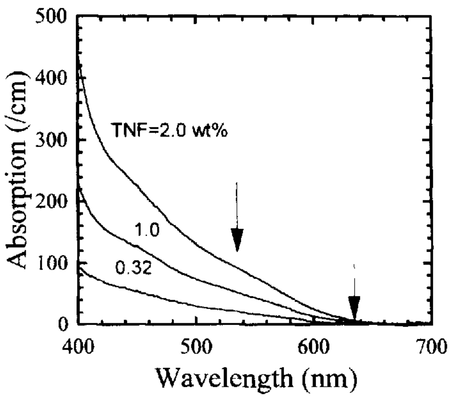

FIGURE 2 Absorption spectra of photorefractive PDLCC films. The writing (532 nm) and reading (633 nm) wavelengths are shown as arrows.

The weight ratio of E7 and copolymer were set to be around 80:20 and the concentration of TNF were changed to be 2.0, 1.0, and 0.32 wt%. Since the copolymer contain the carbazole units in the side chain, copolymer and TNF form charge-transfer complexes and the absorption coefficients in the visible region increase with increasing TNF, which is favorable for photoconductivity and resultant photorefractivity.

3. HOLOGRPHIC RECORDING

The holographic gratings were recorded by means of a frequency-doubled Nd-YAG laser of 532 nm wavelength. The fringe spacing was 2.8 μm and the applied dc field was 0.3 V/μm. The diffracted beam intensity was monitored in the Bragg diffraction direction.

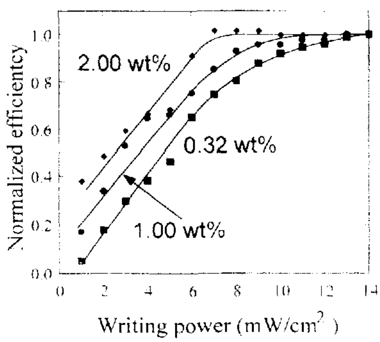

FIGURE 3 Diffraction efficiencies are plotted versus writing beam power.

The absolute value of the diffraction efficiency increases with increasing TNF concentration and the maximum value reached to around 40 %. As shown in Figure 3, the sensitivity was improved by increasing the TNF concentration. The grating was created by irradiating at a low power (around 1 mW/cm^2) of writing beams, while maintaining a high diffraction efficiency of around 15 %.

4. DEMONSTRATION OF EDGE-ENHANCEMENT OF OPTICAL IMAGES

It is known that the edge-enhancement of the two-dimensional optical image is produced by means of real-time holography in inorganic photorefractive crystals [19]. In this section, we demonstrate the same effects by using photorefractive PDLCCs described here.

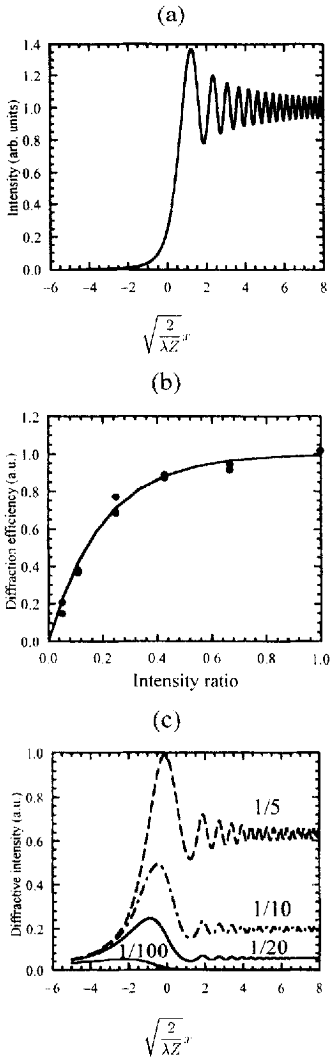

FIGURE 4 Simulation of edge-enhancement of two-dimensional optical image. (a) input signal of edge-image, (b) diffraction efficiencies versus intensity ratio of writing beams, and (c) calculated output images for various intensities of reference beam.

Frigure 4 shows simulation results of edge-enhancement of two-dimensional optical image by means of holographic recording characteristics. Figure 4(a) shows the intensity distribution at the edge of the two-dimensional optical image produced by a pattern mask. The diffraction pattern from such pattern edge is given by

$$u(x,y) = \delta(f_y)\frac{1}{i\lambda Z}\exp\left(ikZ + ik\frac{x^2}{2Z}\right)\left[\frac{1}{i2\pi f_x} + \frac{1}{2}\delta(f_x)\right] \quad (1)$$

with $f_x = x/\lambda Z$ and $f_y = y/\lambda Z$, where Z is the distance between the mask pattern edge and observation screen. In our holographic recording medium, the diffraction efficiency was strongly dependent on the intensity ratio of writing beams as shown in Figure 4(b) because the fringe visibility depends on the ratio. According to both results described in Figures 4(a) and 4(b), we can estimate the reconstructed signals as shown in Figure 4(c) and the edge of optical image was enhanced. In fact, the edge enhancement was observed by using the following experimental setup and our material.

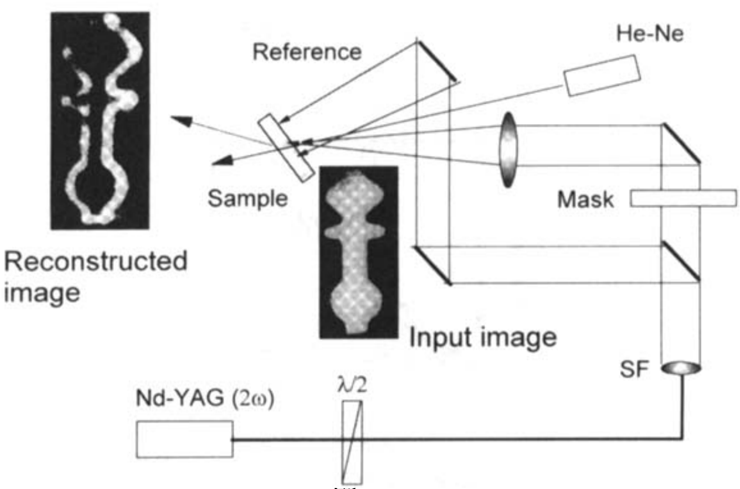

FIGURE 4 Experimental setup for edge enhancement of two-dimensional optical image and input and reconstructed images.

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