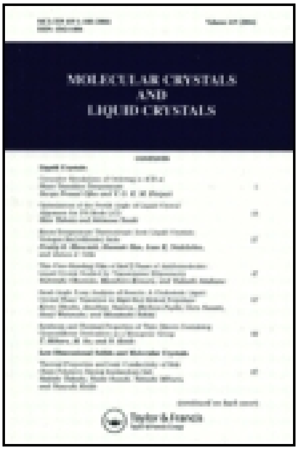

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Functionalized Polarization Gratings in Azo-Dye Doped Polymer Films

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Polarization phase gratings have been prepared in an azo-dye doped polymer by the use of two orthogonal polarized beams and we have extensively characterized the polarization gratings from the point of view of the beam polarization. The polarization gratings diffract the probe beam and convert the polarization state at the same time. The experimental results are in good agreement with the theoretical expectation on the basis of the Jones calculus.

Keywords: azobenzene; diffraction grating; polarization hologram

1. INTRODUCTION

Because of the structural flexibility both at the molecular and bulk levels, organic materials are emerging as a very important class of real-time optical recording materials to be used for generating necessary nonlinear optical functions for the technology of photonics [1]. Since the possibility of recording polarization holographic gratings in guest-host systems containing azobenzene was defined first by Todorov *et al*. [2], many kinds of materials including guest-host polymers and azobenzene side chain polymers have been presented [2–19]. When the azo dye moieties absorb light with an appropriate wavelength, the *trans* moieties undergo a structural change to the

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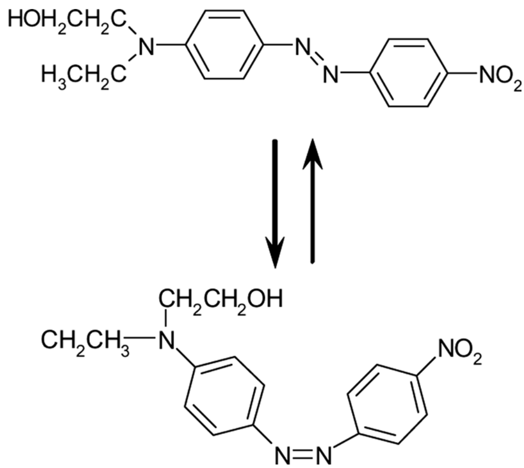

FIGURE 1 Chemical structure of azobenzene dye molecule with *trans* and *cis* configurations.

cis form as shown in Figure 1. The mechanism of laser-induced refractive index change in these materials has been attributed to a statistical reorientation of the azobenzene chromophores perpendicular to the polarization of the incident electric field of the pump laser beam. Their success depends on the exploitation of several unique electrical and optical properties, and on the development of the physics, chemistry and materials science necessary to optimize those properties. Nikolova *et al*. investigated polarization wavefront conjugation by means of four-wave mixing in rigid solutions of azo-dyes [3]. The polarization holographic recording originated in the photoinduced reorientation of the azo-dye molecules and the recorded information could be erased by thermal process. Birabassov *et al*. presented that cellulose acetate films doped with the azo dye could store and reconstruct the polarization state of an elliptically polarized object beam by use of polarization and intensity holograms [13]. These unique features are preferable to reversible holographic media because the recorded information can be erased by either optical or thermal processes.

In the present article we extensively characterize the polarization grating generated in azo-dye doped polymer film. The polarization grating could be formed in the polymer film by means of a polarization holographic technique. The resulting gratings can control both the polarization state and propagation direction of the laser beam.

2. MATERIALS

In the present article, we used the laser sensitive materials consisting of the polymer matrix and the azo-dye molecules in order to fabricate the polarization gratings. The organic polymer films doped with the azo-dye molecules were prepared by the following method. Commercially available poly(methyl methacrylate) as the polymer matrix and 4-[N-(2-hydroxyethyl)-N-ethyl]amino-4′-nitroazobenzene as the doped dye (Aldrich Co. Ltd.) were used without further purification. Figure 1 shows the molecular structure of the azo-dye in the *trans* and *cis* configurations. An azo-dye doped polymer film in this study was prepared by a spin-coating method using a chloroform solution at a weight ratio of azo-dye and polymer of 3:97. After spin coating the solution on the glass substrates, the films were dried at 80°C in order to remove the residual solvents. The two glass substrates were pressed together at 125°C for 1 h and the sandwich structure was formed.

3. EXPERIMENTS

Polarization grating was written using two orthogonal circularly polarized, mutually coherent frequency-doubled Nd:YAG laser beams, which emits cw 523-nm light, with an intensity of 8.0 mW each, incident on the sample. The two writing beams with equal intensities crossing at $\theta = 6.8^\circ$ angle impinge upon dye-doped films. It is known that the interference pattern of two coherent waves with orthogonal circular polarizations has a constant intensity but a polarization state that is periodically modulated [19–22]. The diffraction efficiency of the first-order diffracted beam from the recorded gratings in transmission mode was probed with a linearly or circularly polarized He−Ne laser (633 nm) beam, which is incident normal to the sample surface as shown in Figure 2. To characterize the grating recorded by the

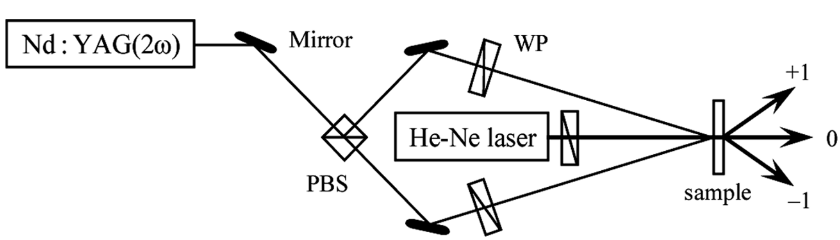

FIGURE 2 Experimental setup for measurements of polarization gratings. PBS: polarizing beam splitter, WP: quarter- or half-wave plate.

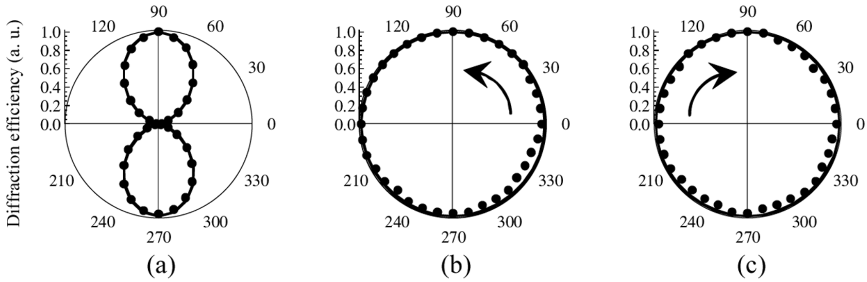

FIGURE 3 Polarization analysis of the beams diffracted from the polarization gratings. (a) Zero, (b) +1th-, and (c) −1th-order diffracted beams were characterized for linear incident polarization.

polarization holographic technique we measured diffraction efficiency which was defined as the intensity ratio of the first order diffracted beam to the incident beam. In addition, the polarization state of the diffracted beam was characterized by Glan-Thompson polarizing prisms and a quarter-wave plate. All measurements were performed at room temperature.

4. RESULTS AND DISCUSSION

The polar plots displayed in Figure 3 represent our polarization analysis when the probe is linearly *s* polarized. Polarization of the +1th-order diffraction beam was left-circularly polarized, while that of the −1th-order diffraction beam was right-circularly polarized. The 0th-order polarization state was linearly *s* polarized, that is, the same as that of the probe beam. The theoretical curves in Figure 3 were calculated by using of the Jones analysis [11]. The polar plots displayed

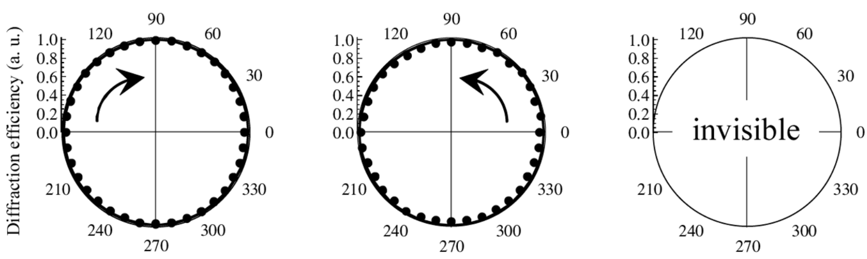

FIGURE 4 Polarization analysis of the beams diffracted from the polarization gratings. (a) Zero, (b) +1th-, and (c) −1th-order diffracted beams were characterized for right-circular incident polarization.

in Figure 4 represent our polarization analysis when the probe is right-circularly polarized. The +1th-order polarization state was left-circularly polarized, while the −1th-order polarization state was invisible. The 0th-order polarization state was right-circularly polarized, that is, the same as that of the probe beam. This result was also explained by the theoretical calculation.

5. CONCLUSIONS

We extensively characterize the polarization grating generated in azo-dye doped polymer film. When the azobenzene molecules absorb light with an appropriate light wavelength, the *trans* moieties undergo a structure change to the *cis* form. Since the *cis* isomer is thermally unstable at room temperature, the azobenzene molecules reorient perpendicular direction to the pump polarization as the *trans* form. In this study, we attempted to induce a spatial and periodical reorientation distribution (i.e., anisotropic grating) in azo-dye doped polymer film by means of polarization holography. The resulting gratings can control the propagation direction and convert the polarization state of light at the same time. The experimental results are in good agreement with expectation on the basis of the Jones calculus by considering a reorientation distribution of the azo-dye molecules according to the pump interference polarization.

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