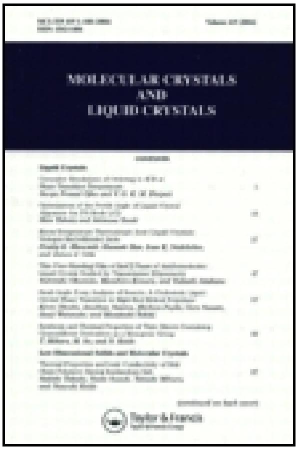

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

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

Optical Gratings Fabricated by Deposition of Liquid Crystalline Polymer Films with Linearly Polarized UV Laser

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Version of record first published: 04 Oct 2006

To cite this article: Toshiaki Itadani & Koichi Saito (1998): Optical Gratings Fabricated by Deposition of Liquid Crystalline Polymer Films with Linearly Polarized UV Laser, Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals, 314:1, 267-272

To link to this article: http://dx.doi.org/10.1080/10587259808042486

Mol. Cryst. Liq. Cryst., 1998, Vol. 314, pp. 267-272
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Optical Gratings Fabricated by Deposition of Liquid Crystalline Polymer Films with Linearly Polarized UV Laser

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Polyimide layer on a glass substrate was exposed with a linearly-polarized UV laser through a photo-mask having line-and-space patterns of 2.2 μm. UV laser chemical vapor deposition of liquid crystalline polymer was carried out on the treated substrate. The deposited films showed optical diffraction due to periodic change of molecular orientation of liquid crystalline polymer. The efficiency of optical diffraction was changed with polarization of incident light.

Keywords: molecular orientation, vacuum deposition, photo-polymerization

INTRODUCTION

Recently, a number of reports have appeared on the control of molecular orientation by a polarized light in the field of optical and electronic devices consisting of liquid crystalline compounds[1-4]. In these cases, the formation of liquid crystal (LC) or liquid crystalline polymer (LCP) layer was performed by such a wet process as spin-coating. On the other hand, dry processes are preferable for preparing functional polymeric thin film, because it is solvent-less process, allows precise thickness control, and can produce uniform, highly pure thin films.

We reported the linearly-polarized laser chemical vapor deposition (LLCVD) of side-chain type LCP films in the previous paper[5]. Thereafter, we found that the polyimide (PI) layer exposed to UV laser had an ability to align a LCP layer and presented a new method for fabrication of the polymer films whose molecular orientation can be controlled in a micrometer size[6]. In this paper, we report fabrication and evaluation of thin film type optical gratings whose refractive index modulation was attributed to the periodic change of molecular orientation.

EXPERIMENTAL

The procedures in this work are schematically illustrated in Fig. 1; (1) spin-coating, (2) pre-exposure, and (3) film deposition. PI resin (Nissan Chemical Industries, SE-150) was spin-coated on a soda glass plate. The coated glass was cured at 236 °C for 1 hour. Then, a linearly polarized KrF excimer laser (A) (λ = 248 nm, typical fluence of 2 to 3 mJ cm^{-2}, 100 pulses) was irradiated on the coated layer through a photo-mask having line-and space patterns of 2.2 μm width in the air at room temperature.

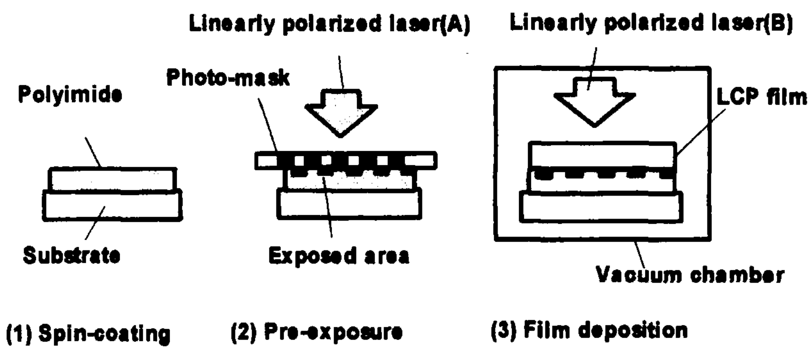
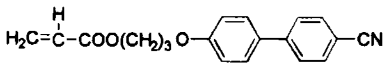


FIGURE 1 The schematic illustration of process for optical gratings

LLCVD of LCP was carried out on the pretreated substrate. The chemical structure of a monomer used for the deposition is shown in the formula (1). This monomer can be photo-polymerized to give a side chain type LCP.



(1)

The films were deposited for 30 minutes upon laser irradiation to the substrates. The KrF excimer laser was used at a fluence of 2 to 3 mJ cm^{-2} , a repetition rate of 10 Hz, and the polarization direction of laser (B) was 45° tilted to that of the pre-exposure laser beam.

The deposited films were analyzed with a polarized optical microscope. Molecular orientation of films was determined by optical birefringence. The intensity of the light beams diffracted by the films was measured with a He-Ne laser and a photo-diode.

RESULTS AND DISCUSSION

Figure 2 shows the photomicrographs of a deposited film using crossed polarizers with changing the angle between the polarizer and the direction of the film.

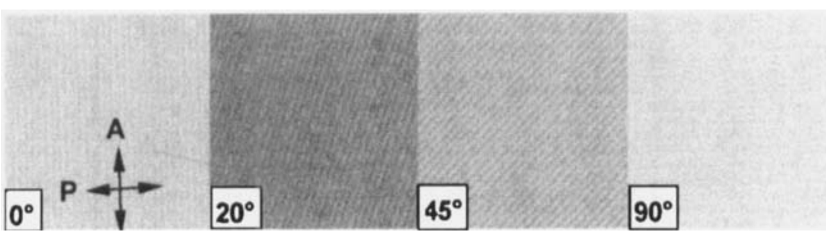


FIGURE 2 Photomicrographs of a deposited films using crossed polarizers. The arrows "P" and "A" indicate the directions of polarization of light through a polarizer and an analyzer.

The stripe structure was well observed at 20 and 45°, where either of the neighboring strips became dark. The dark strips at 20 and 45° correspond to the pre-exposed and non-exposed areas. Optical retardation of these areas were 128 and 105 nm, respectively, and were larger than those of films deposited with the monomer used previously[6]. These results indicated that directions of molecular orientation in the respective areas were tilted 20 and 45° measured counterclockwise from the stripe. On the other hand, the polarization directions of pre-exposure and deposition laser beams were perpendicular to and 45° tilted to the stripe. These relations between directions of molecular orientation and laser polarization were supported by the polarized FT-IR spectra reported in the previous paper, suggested that the side chain of LCP was aligned perpendicular to the polarization of the pre-exposure laser in the pre-exposed area[6].

Figure 3 shows the change of intensities of diffract light with direction of polarization of incident light. The odd order diffraction beams were dominant because the film had a same width of rectangular change of refractive index. The diffraction efficiency was largest when the polarization of incident light was perpendicular to the stripe.

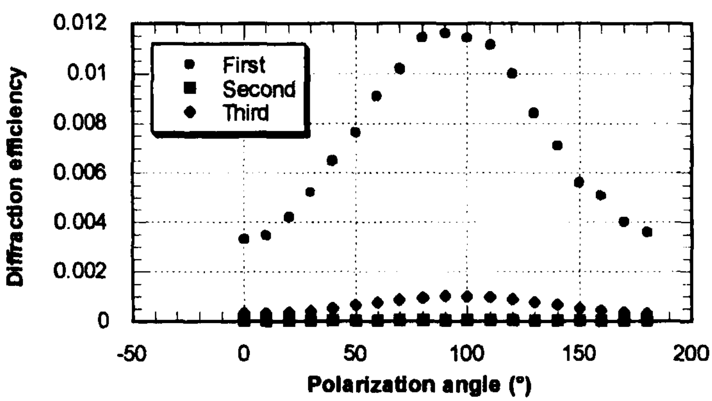


FIGURE 3 Change of diffraction intensities with direction of polarization of incident light

The dependency of diffraction intensity on polarization direction is observed in the grating period comparable to the wavelength. In the present case, the period was ca. 7 times larger than the wavelength. Therefore, these results were due to the birefringence of the deposited film.

Intensities of optical diffraction of thin film type phase gratings was calculated by the Fourier transform of optical transmittance function of gratings. Table I shows the measured and calculated diffraction intensities of the film. The calculation was performed with the model of rectangular change of optical retardation with a same strip width.

TABLE I Diffraction intensities of a thin film type grating

Diffraction order	First	Second	Third	Retardation
measured	0.0116	0.00003	0.00101	-
calculated	0.0116	0	0.00389	3.68nm

These results suggested that the retardation between the strips was small compared to those of the each strips.

CONCLUSION

Optical gratings were fabricated by our linearly polarized laser technique. Optical diffraction was induced by the periodic change of molecular orientation. The efficiency of diffraction can be increased with increasing the degree of orientation or thickness of the film. Although the efficiency was very low, this technique have potentials for fabrication of optical devices such as polymer integrated optics, phase gratings, and micro-lens arrays.

Acknowledgments

We thank Drs. H. Niino and A. Yabe of National Institute for Materials and Chemical Research for helpful discussions. T.I thanks Mr. Ohnishi of Kuraray for his suggestions. This work was conducted as part of the program, "Advanced Chemical Processing Technology", commissioned to the Advanced Chemical Processing Technology Research Association from the New Energy and Industrial Technology Development Organization, carried out under the Industrial Science and Technology Frontier Program administered by the Agency of Industrial Science and Technology, the Ministry of International Trade and Industry.

References

[1.] K. Ichimura, Y. Suzuki, T. Seki, A. Hosoi and K. Aoki, *Langmuir*, **4**, 1214 (1988).

[2.] W. M, Gibbons, P. J. Shannon S. T. Sun and B. J. Swetlin, *Nature*, **351**, 49 (1991).

[3.] M. Schadt, K. Schmitt, V. Kozinkov and V. Chigrinov, *Jpn. J. Appl. Phys.*, **31**, 2155 (1992).

[4.] M. Hasegawa and Y. Taira, *J. Photopolym. Sci. Technol.*, **8**, 241 (1995).

[5.] T. Itadani, K. Saito, T. Akiya, S. Nagata, H. Niino and A. Yabe, *Jpn. J. Appl. Phys.*, **34**, L566 (1995).

[6.] T. Itadani, K. Saito, H. Niino and A. Yabe, *Appl. Phys. Lett.*, **70**, 1399 (1997).