RE

AD-A280 505

Form Approved
OMB No 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	June 17, 1994	Technical Report #14

4. TITLE AND SUBTITLE
Optically Induced High Efficiency Gratings in Azo Polymer Films

5. FUNDING NUMBERS
N00014-93-1-0615

6. AUTHOR(S)
P. Rochon, J. Mao, A. Natansohn and E. Batalla

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Department of Chemistry
Queen's University
Kingston, Ontario
K7L 3N6 Canada

8. PERFORMING ORGANIZATION REPORT NUMBER
14

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Department of the Navy
Office of Naval Research
800 North Quincy Street
Arlington, VA 22217-5000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
submitted to "Polymer Preprints"

12a. DISTRIBUTION AVAILABILITY STATEMENT
Reproduction in whole or in part is permitted for any purpose of the United States Government. This document has been approved for public release and sale, its distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

Going beyond the usual orientation of azobenzene groups within amorphous polymers, an increased amount of incident light may produce physical gratings of the order of magnitude of the wavelength. The diffraction efficiency of such gratings can reach 28% or even more. The surface profile of the grating can be observed with an atomic force microscope. Such gratings can be used to couple beams optically into the film and out of the film, as well as for waveguides.

14. SUBJECT TERMS
diffraction gratings, efficiency, azo polymers

15. NUMBER OF PAGES
4

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
unclassified	unclassified	unclassified	unlimited

OFFICE OF NAVAL RESEARCH

GRANT: N00014-93-1-0615

R&T CODE: 4132081

Scientific Officer: Dr. Kenneth J. Wynne

TECHNICAL REPORT NO. 14

Optically Induced High Efficiency Gratings in Azo Polymer Films

by

P. Rochon, J. Mao, A. Natansohn and E. Batalla

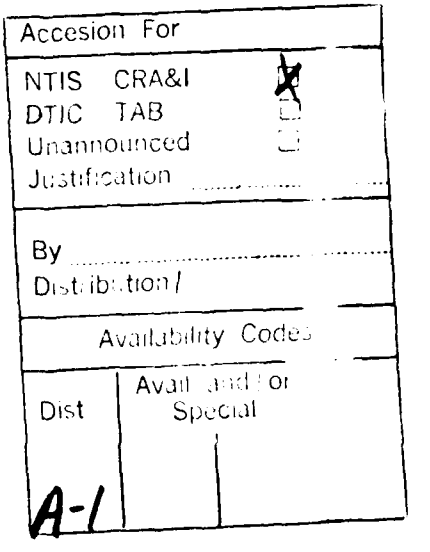
Submitted for publication

in

Polymer Preprints

Department of Chemistry
Queen's University
Kingston, On., Canada

June 17, 1994



OPTICALLY INDUCED HIGH EFFICIENCY GRATINGS IN AZO POLYMER FILMS

by P. Rochon[1], J. Mao[1], A. Natansohn[2], and E. Batalla[1]

[1]Department of Physics, Royal Military College of Canada, Kingston, Ontario K7K 5L0 and [2]Department of Chemistry, Queen's University, Kingston, Ontario, K7L 3N6

INTRODUCTION

Polymer materials have been recently studied for their possible use in the optoelectronic and optical storage fields. These material present major cost and processing advantages and thus make these very attractive candidates for these rapidly advancing technologies. It has recently been shown that optical information can be optically stored and erasable in azo-polymers[1]. This is accomplished by optically inducing a rearrangement of these anisotropic molecules thereby inducing a controllable birefringence and dichroism in an azo-polymer thin film.

The ability to change the refractive index properties of azo-polymers has lead us to investigate the possibility of using these films as erasable holographic storage media and to investigate the properties of these films when these are used as holographic volume gratings. The possible use of such gratings as coupling agents for light to be transmitted in a film wave guide has been an important consideration.

The present work reports the observation and recording of highly efficient, stable, erasable diffraction grating on azo-polymer films. The efficiencies substantially exceed those expected from the creation of volume phase gratings which can be recorded by optically induced birefringence.

EXPERIMENT

The measurements reported here were made on 4'-[[2-(acryloyloxy)ethel]ethyl-amino]-4-nitroazobenzene (pDR1A) polymer thin films. The polymer preparation has already been reported[1,2]. The films were made by dissolving the polymer in tetrahydrofuran (THF) and spin coating onto a glass substrate. The film thicknesses were of about 200 nm. The films were then heated above the glass transition temperature of the polymer, ca. 95 C., in order to remove remaining solvent. The films' optical density was typically OD 1 at 514 nm.

The gratings were optically inscribed onto the films using a setup illustrated in figure 1. The writing beam was formed by expanding and collimating an argon laser beam at 514 nm to a diameter of three millimeters. This beam was incident onto the sample holder which consisted of a sample stage set at right angles to a front surface mirror. The portion of the beam which strikes the mirror is reflected back onto the sample to interact with the direct beam and form an interference pattern on and throughout the sample. The wavelength of the laser as well as the angle of incidence, α, of the writing beam to the sample holder can be adjusted to change the spacing of the interference pattern. The light in the interference pattern is absorbed by the polymer film and the formation of a grating has been observed.

The time evolution of the optically induced grating is monitored using a HeNe probe beam at 633 nm. This beam is used because it is not absorbed by the film and can be left on without disturbing the results. The probe beam is nearly parallel to the writing beam and the films are sufficiently thin that the Bragg condition on the angle of incidence is not a critical parameter in these measurements. For thicker films care is taken to properly align the probe beam, although a measurement of the absolute diffraction efficiency can easily be performed as a function of angle in a subsequent experiment to the inscription process.

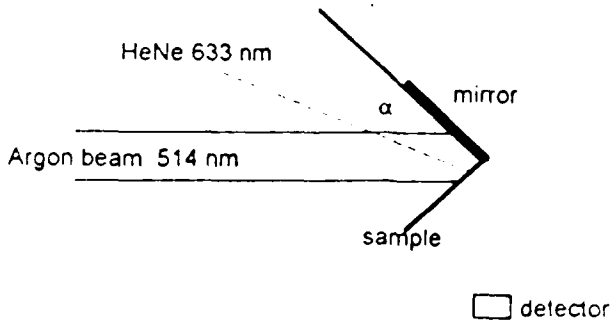


Figure 1: Grating inscription setup

RESULTS AND DISCUSSION

Typical results for the diffraction efficiency of the optically induced grating are presented in Figure 2. The results show that there is creation of a grating at short times, with a time constant on the order of 10 to 2 seconds for the writing powers used here. This is followed by a slower build up of a highly efficient diffraction grating with characteristic time constants in the thousands of seconds.

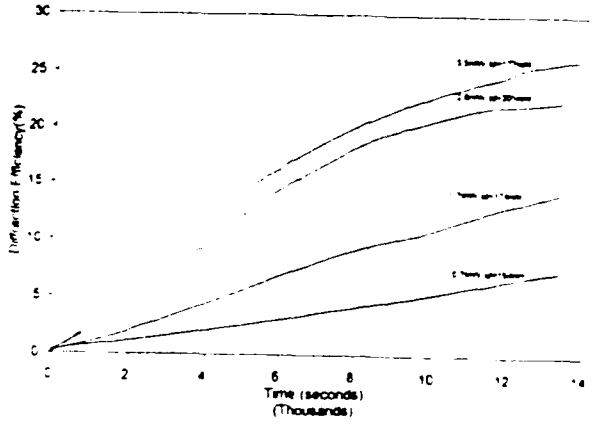


Figure 2: Diffraction efficiency of pDR1A films as a function of time for various writing beam power.

We associate the observed behavior with two distinct processes for creating the diffraction. In the first case the diffraction efficiency appears to saturate at about 0.2 %. This behavior can be explained as being due to the optical creation of a birefringence grating throughout the sample. The light which is reflected by the mirror will be partially linearly polarized and local birefringence can be induced in these polymers by using linearly polarized light[1]. Using Kogelnick's expression for the efficiency of a volume phase grating[3] we obtain a birefringence of $\Delta n \cong .05$, a typical value for the optically induced birefringence already observed on this material[1-2]. We also have confirmed this interpretation of this initial grating formation by stopping the writing process after 10 seconds and erasing the grating optically using unpolarised light to overwrite on the film.

The second part of the diffraction behavior appears to come from an optically induced mass diffusion of the polymer. The grating produced during this part of the writing is permanent as long as the sample's temperature is kept below the glass transition temperature. The grating can be erased by heating the film above the glass transition temperature and a new grating can be written onto the film after it has cooled. There appears to be no permanent damaged caused to the film in such a writing/erasing cycle. We also note that other gratings of differing orientation and grating spacing can be written on top of already existing gratings. It is also possible to write multiple gratings by using the multiple lazing lines simultaneously.

An atomic force microscope was used to obtain a surface profile of the film in order to confirm that a physical displacement of polymer material is involved in the creation of the grating. A typical result is presented in figure 3. Again using Kogelnick's expression for a thick grating and using a typical refractive index of 1.6 for this polymer we obtain a grating depth of 150 nm, in keeping with the observed results. The grating profile exhibits a sinusoidal behavior which echoes the power density profile of the interfering writing beams. The grating spacing could be adjusted from 360 nanometers to over 1 micron using 514 nm wavelength at various angles of incidence. The fine grating spacing achievable is reminiscent of the recently reported sub micron periodic structures on polymer surfaces[4-5].

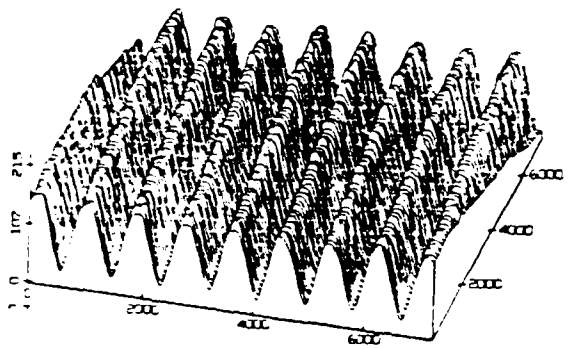


Figure 3. Atomic force microscope surface profile.

The grating formation rate is initially directly proportional to the writing beam power which suggests that the important parameter is the total energy absorbed by the polymer. The diffraction efficiency is also seen to saturate at about 28 % in these samples, thus is what would be expected for a grating thickness approaching the films thickness of about 170 nm. The true limit to the efficiency achievable may yet be higher for thicker films.

CONCLUSION

Optically induced diffraction gratings are seen to have diffraction efficiencies which far exceed that which could be the result of induced birefringence in the polymer film. The present preliminary study indicates that polymer diffusion is at the origin of the grating formation and indicate that thermal effects may be involved although no polymer ablation is observed and that the samples are recoverable by heating above the glass transition temperature of the polymer. We expect that higher efficiencies may be achievable and that gratings with much finer spacing, as low as 250 nm, could easily be recorded. Since the gratings are optically induced a number of applications in the optoelectronic fields present themselves. Two primary candidates are in the fields of optical wave guides and optical coupling to films.

ACKNOWLEDGMENT. We wish to thank the Office of Naval Research (U.S.), NSERC (Canada), and the Department of National Defence Canada for funding.

REFERENCES

1. A. Natansohn, P. Rochon, J. Gosselin and S. Xie, Macromolecules, 25, 2268 (1992).
2. A. Natansohn, S. Xie and P. Rochon, Macromolecules, 25, 5531 (1992).
3. H. Kogelnik, Bell Syst. Tech. J., 48, 2909 (1969).
4. M. Bolle, S. Lazare, M. LeBlanc, A. Wilmes, Appl. Phys. Lett. 60, [illegible] (1992).
5. H. Hiraoka and M. Sendova, Appl. Phys. Lett. 64, 563 (1994).