Surface Relief Holograms on azo-polymer film

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Abstract

Surface relief holograms are fabricated by means of irradiation of laser interference patterns. The diffraction efficiency and the surface relief depth depend on the writing energy and the polarization of the writing laser beam. This structure is very stable at temperatures under glass transition temperature T_g and can be erased by heating above T_g. We proposed a new technique to control the surface relief structure. The electric charge was deposited on the surface relief grating in a corona-depositing poling setup in an oven. The first-order diffraction efficiency measured before and after corona discharge increased from about 0.24 % to about 28 %. This diffraction efficiency increase is mainly caused by the increase of the relief depth caused by the electric charge. The relief depth is increased from 20 nm to 350 nm by corona charging..

1. Introduction

Polymeric materials are the most promising organic materials for electrooptic devices and memory devices. The recording of polarization holographic gratings using azobenzene-containing polymer films as photoanisotropic materials has been reported.[1] This photoinduced anisotropic effect is due to trans-cis-trans isomerization and the orientational effects of the azo-dye chromophore. Direct fabrication of relief structures in azo-polymers has been reported in the past several years.[2-4] A surface relief structure is recorded through photoisomerization and the movements of the polymer chains. This is a one-step fabrication technique. A surface relief structure is fabricated by irradiation of interference laser fringes onto azobenzene functionalized polymers such as side-chain-type and main-chain-type azo-polymers. The diffraction efficiency and the surface relief depth depend on the writing energy and the polarization of the writing laser beam.[5] This structure is very stable at temperatures below the glass transition temperature T_g and can be erased by heating above T_g. This fabrication mechanism is not well understood at present, but several models have been proposed.[6-8]

We have recently reported that the diffraction efficiency of the surface relief structure can be markedly increased by corona charging.[9] Moreover, such a hologram exhibits nonlinearity, because the orientation of the azo chromophore and the increase in the diffraction efficiency are performed concurrently by corona charging. Surface relief grating fabrication and the modulation of a surface relief electrooptic grating have been reported.[10]

In this paper, surface relief holograms are fabricated on azo-polymer films by irradiation of interference laser fringes. Temperature dependence of the increase of the surface relief structure is measured. The diffraction efficiency of the hologram is controlled by irradiation of the laser beam with corona charging above T_g.

2.Surface Deformation Method

The side-chain azo-polymer, poly-orange tom-1 isophoronediisocyanate, is used in this study. Figure 1 shows the chemical structure the material. The glass transition temperature T_g is 136°C. The absorption peak and the cut-off wavelength of the dye are 440 nm and 560 nm, respectively. This polymer is dissolved in cyclohexanone. Samples of 1~5 m thickness are prepared by spin-coating on a slide glass plate. The refractive index of the film is measured as 1.65 at a wavelength of 633 nm by the m-line technique. The surface relief grating is fabricated by the irradiation of two-beam interference fringes.

A polarized Ar-ion laser beam at a wavelength of 488 nm is used as the light source. The laser beam is collimated to 6 mm in diameter, half of the laser beam is reflected by a mirror and the two beams interfere on the sample. The setup is strong arrangement in the vibration. The angle between the sample and the mirror is 90° and the period of the grating can be adjusted by varying the angle θ between the beam propagation axis and the mirror plane.

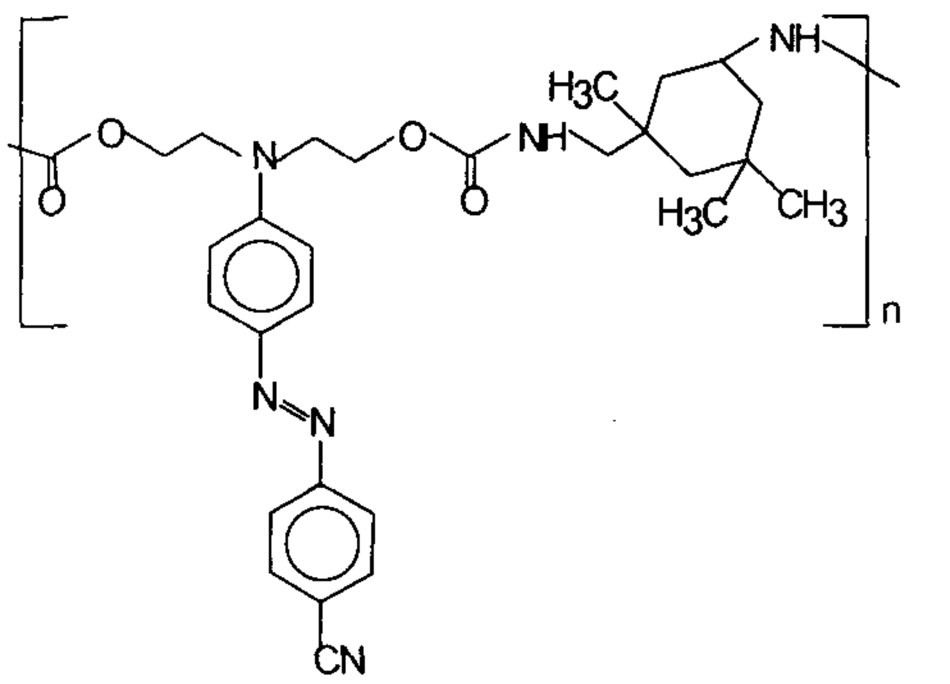


Fig. 1 Chemical structure of the material.

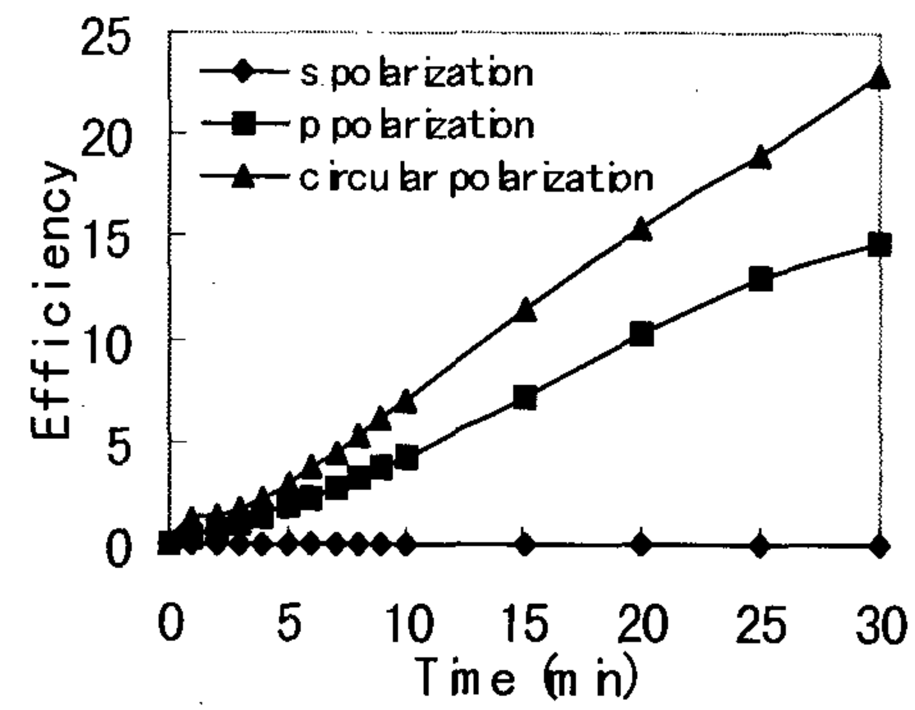


Fig. 2 Polarization dependence of the diffraction efficiency.

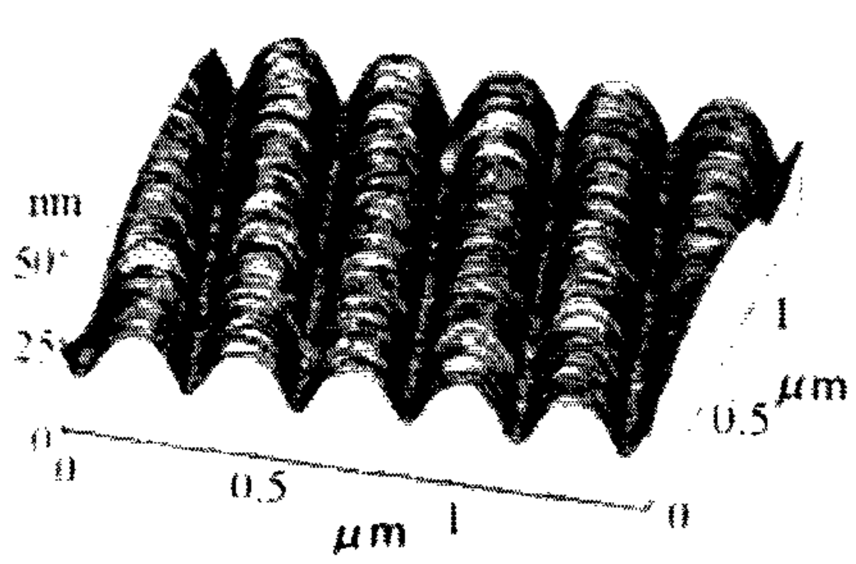


Fig. 3 AFM image of surface relief grating.

Figure 2 shows the polarization dependence of the diffraction efficiency. The period of the surface relief grating is selected as 1 μm. There is a strong polarization dependence of the writing laser beam. High diffraction efficiency is obtained using a p- or circularly polarized writing beam. The relief structure is not recorded using an s-polarized writing beam. High diffraction efficiency can be obtained in a short time by high-power recording.

Figure 3 shows a relief profile with its depth of 16nm.

3. Diffraction Efficiency Increase of Surface Relief Structure

We have recently confirmed that the diffraction efficiency and the relief depth of a surface relief structure is markedly increased by corona charging at temperatures near or above its T_g.[9] The mechanism is not clearly understood, but we consider that the relief depth increases as a result of the Coulomb force exerted by electric charge; therefore the diffraction efficiency is increased. This increase depends on the corona charging conditions, specifically, the corona charging temperature, the applied voltage and the corona charging time. The electric charge was deposited on the surface relief grating using a corona deposition poling setup in an oven. A sharp needle electrode was positioned above the ground electrodes. A film with surface relief structure was placed on the ground electrode. The distance between the polymer film and the needle electrode was 7 mm. In the corona charging process, the voltage was applied at a temperature near T_g and the polymer film was heated to the corona charging temperature with the voltage applied, because the surface relief structure is thermally erased above T_g without the applied voltage.

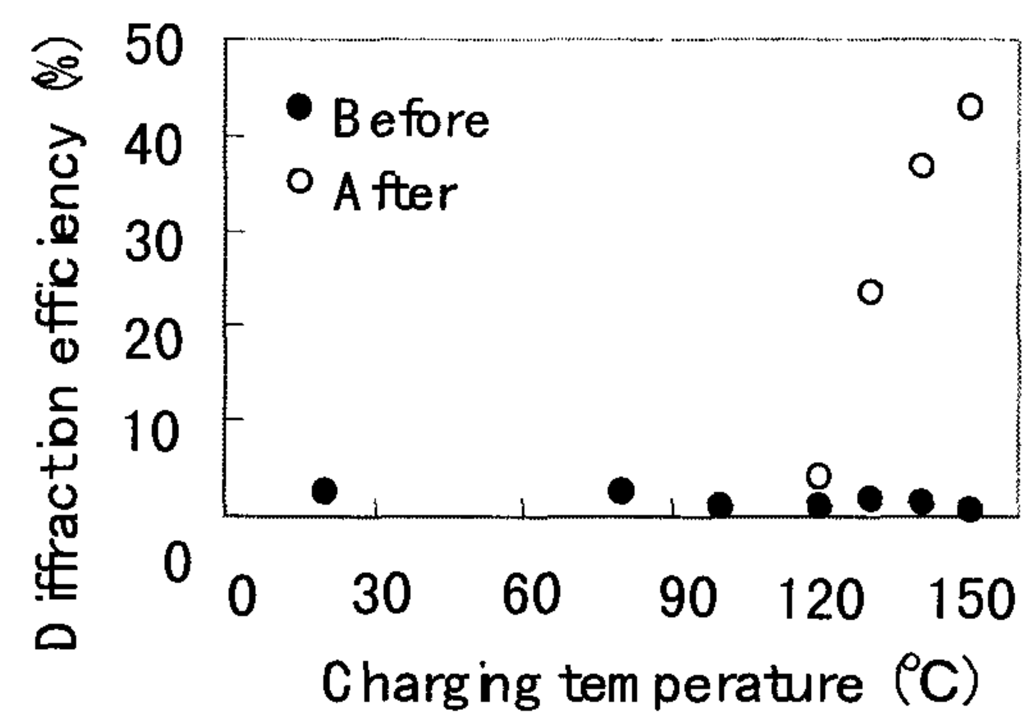


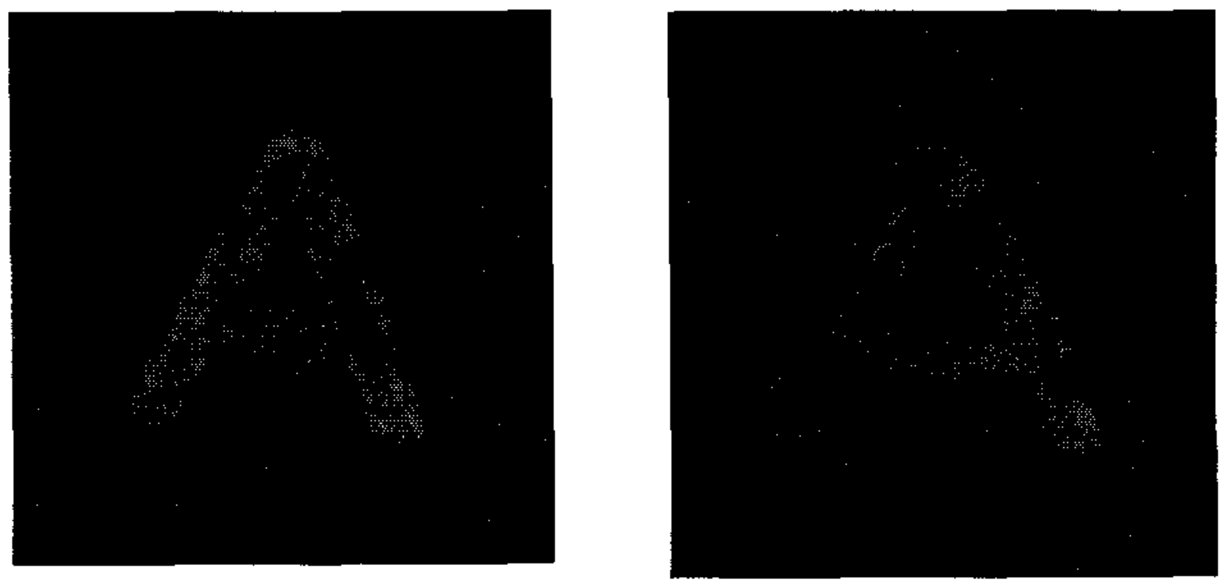
Fig. 4 Temperature dependence of diffraction efficiency of surface relief gratings before and after charging.

Figure 4 shows a temperature dependence of diffraction efficiency increase. Surface relief grating was recorded by circularly polarized Ar-ion laser. The laser beam power was 50 mW/cm^2 for 20 min. After corona charging for 20 min, the polymer film was cooled to room temperature with the applied voltage. During the corona charging process, a voltage of 8 kV was applied. Diffraction efficiency was increased near or above T_g. The increase can be used to increase the initially low diffraction efficiency of the recorded hologram.

Next, we examined Fourier transform hologram recording using the photoinduced surface modulation technique.A circularly polarized Ar-ion laser beam with a wavelength of 488 nm was used. The laser beam was collimated to a 6 mm diameter and separated by a beam splitter. The Fourier transform hologram was recorded on an azo-polymer film with a thickness of about 2 μm. The letter A, 4 mm tall and 3 mm wide, was used as the object. The beam power in front of the object was I_1 = 118 mW/cm^2. The object beam was Fourier transformed on the azo-polymer film using a lens with a focal length of 100 mm. The reference beam power was I_2 = 118 mW/cm^2 and the recording time was 1 min.

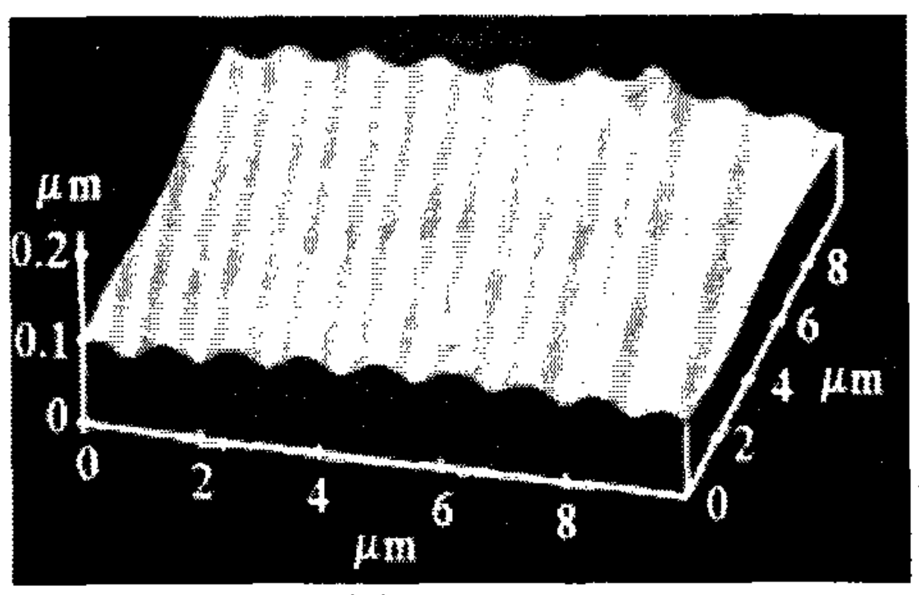
The reconstructed image is shown in Fig. 5(a). This reconstructed image was observed using a He-Ne laser beam. The diffraction efficiency of the recorded hologram measured using a He-Ne laser was 1.2%. The electric charge was deposited on the hologram using a corona charging setup in an oven. The hologram was placed on the ground electrode. The distance between the polymer film and the needle electrode was 7 mm. In the corona charging process, the voltage was applied at a temperature near T_g and the polymer film was heated to the corona charging temperature with the voltage applied. After corona charging for 20 min, the polymer film was cooled to room temperature with the applied voltage. During the corona charging process, a voltage of 7 kV was applied at 141 . The first-order diffraction efficiency of the hologram measured before and after corona charging using a He-Ne laser increased from 0.24% to 28.39%. This increase in the corona charging depends on the corona charging conditions, and the increase in the diffraction efficiency of the hologram can be controlled by these conditions. The reconstructed images after corona charging are shown in Fig. 5(b).

We observed the recorded Fourier transform hologram using an atomic force microscope (AFM). The surface profiles of the Fourier transform hologram before and after corona charging are shown in Figs.6(a) and 6(b). The relief depths measured before and after corona charging were about 20 nm and about 350 nm, respectively. This indicates that the increased diffraction efficiency caused by corona charging strongly depends on the increased relief depth of the recorded hologram. We have confirmed that the diffraction efficiency of the hologram increases markedly as a result of corona charging, and the maximum diffraction efficiency is over 30%. The first-order diffraction efficiency of the increased Fourier hologram remained unchanged for several months at room temperature under natural light.

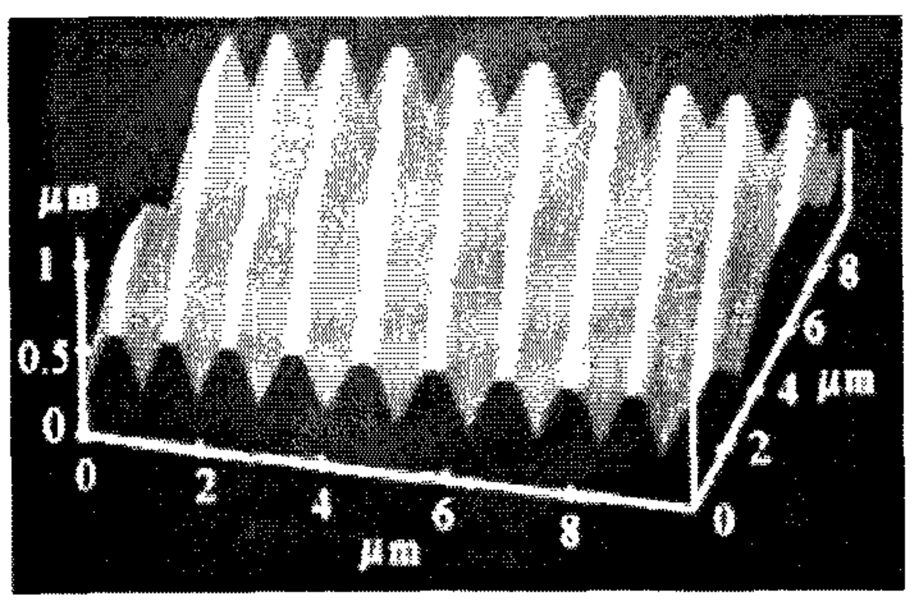


(a) (b)

Fig. 5 The reconstructed images (a) before corona charging; and (b) after corona charging.



(a)



(b)

Fig. 6 Surface profiles of Fourier transform holograms. (a)Before corona charging and (b)after corona charging.

4. Conclusion

We proposed a new hologram recording technique using photoinduced surface deformation on azo-polymer films. Temperature dependence of the increase of the surface relief structure is measured. The first-order diffraction efficiency of the hologram increased from 0.24% to 28.39%. The diffraction efficiency was controlled by the irradiation of a uniform laser beam at a wavelength of 488 nm with corona charging.[11] This recording technique can be applied to holographic memory devices.

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5. Refernces

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