Recording and digital holographic analysis of complex superimposed gratings

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I. Introduction

This paper concerns holographic gratings recording on a new carbazole-based photoresponsive material. The subject of our research is the azopolymer Polyepoxypropil carbazole:Disperse Orange that was used as recording media. Activation of the surface deformation during the laser beam interaction with the material is made by chemically bonding Azo dye Disperse Orange 3 to oligomer poly-N-(epoxypropyl carbazole). Mass transport phenomenon is the physical process responsible for the formation of the surface relief on this material during interferometric laser inscription. The relief symmetrical array is formed directly without additional chemical treatment. The advancement of this paper in comparison to our previous work [1] is the performance of the extra deep surface profile of the volume diffraction gratings (DG) with a complex hexagonal shape. Superimposed DG with 1-, 2- and 3-fold rotation symmetry were successfully fabricated on the obtained thin azopolymer films by using the two-beam multiple exposure technique. The most significant applications of such DG include optical imaging systems for engineering and biology, optical data storage, free space optical communication system as well as optical metrology [2,3]. A major potential application of these particular DG could be the laser wavefront manipulation in a digital holographic microscope(DHM) configuration for collecting more information from the spectrum diffracted by the object, which generally would drop out of the CCD camera.

II. Experimental Section

A. Complex relief gratings recording

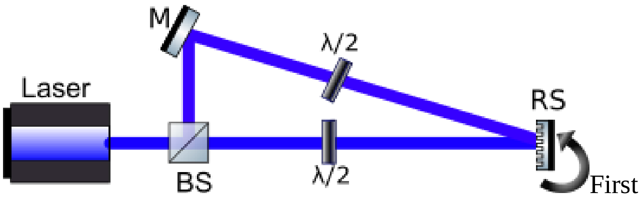


Fig. 1. Holograhic grating recording setup: λ=463nm laser, BS-beam splitter, M-mirror, λ/2 wave plates, RS-rotating stage.

In our study azobenzene polymer has been obtained by reaction of 340 mg poly-n-epoxypropyl carbazole (PEPC) with 34 mg of DO in boiling toluene (2 ml) during 3 hours. All used solvents and reagents were of reagent quality and used without additional purification. 4-[(4'-Nitrophenyl)azo] aniline, Disperse Orange 3 (DO 3) with dye 90% purchased from Sigma-Aldrich. The resultant solution of carbazole-based 4-[(4'-nitrophenyl)azo]aniline-labeled azopolymer called as poly(PEPC-co-DO) was filtered, determined by UV-Vis absorption and used for thin film deposition [1]. In order to obtain films with different thickness resultant solution was diluted with different amounts of toluene. Thin azopolymer films were obtained in equal conditions by spin-coating of initial and diluted solution under 500 rpm for 30 sec and dried at room temperature for a day. The obtained azopolymer thickness was about 1.6 µm.

The holographic set-up used for laser inscription of DG is shown in Fig 1. For inscribing surface-relief-grating, a linearly polarized beam from a DPSS laser was used as the light source. Exposure by interference pattern of the laser beam (473 nm, 1700 mW/cm2) showed ability to direct form surface relief gratings. Due to this property, superimposed surface relief structures were fabricated on the obtained thin azopolymer films by using the two-beam multiple exposure technique. The s-polarized laser beam was split into two equal-intensity beams by using a beam splitter.

The polarisation state of the laser beam strongly influences the grating formation[3], therefore two λ/2 wave plates were used to provide the best polarizations configuration P-P for effective surface relief formation.

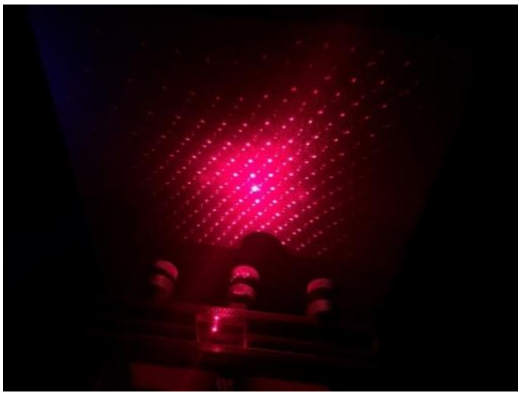


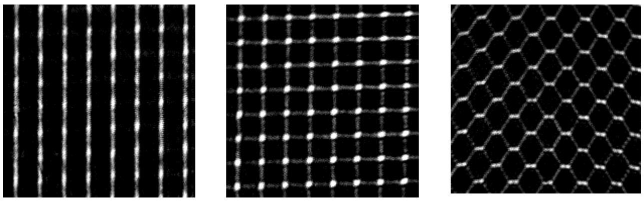
Fig. 2. Picture of the diffraction pattern of the superimposed DG

The azopolymer film mounted on a rotation stage was exposed to the interference pattern for a fixed period of time. After each exposure, the sample was rotated around the surface normal to achieve the required orientation of the grating vector relative to the previous one. To fabricate a superimposed structure with *n*-fold rotation symmetry, the rotation angle was π/n and *n* exposure steps were required. The time period for each exposure was constant and equal to 5 min. Fig. 2 illustrates the array illumination of fine diffraction dots that are transmited through the DG.

III. Measurement Results

A. DHM measurement

In Fig. 3 (a, b, c) the superimposed gratings images obtained by DHM with the of 1-, 2- and 3-fold rotation symmetry are shown. Digital holograms were obtained from an off-axis DHM bright-field configuration in transmission mode.



a b c

Fig. 3. DHM experimental observation of the superimposed diffraction gratings.

DHM had the following components characteristics: microscope objective with magnification 40x and NA= 0.65, laser He-Ne laser (λ=632,8 nm), CCD camera resolution was 2592 pixel x 1944 pixel with pixel size 2.2µm x 2.2µm. The interferometric image was formed by two beams: object beam that directly illuminated the DG surface and the reference beam that was oriented towards the registration plane at a small angle.

For the reconstruction of the grating surface from the interferometric image, the iterative Sparse Phase and Amplitude Reconstruction (SPAR) technique was used. This hologram processing algorythm provides significant noise suppression if compared to conventional Fourier Transform based techniques, it was proven in [4]. The determined period of the surface relief (SRG) gratings is Λ=5 µm. The investigated area of was 40x40 µm that is around 8 periods of the grating. The reconstructed surface of the superimposed DG represent regularly spaced hexagonal relief.

B. AFM measurements

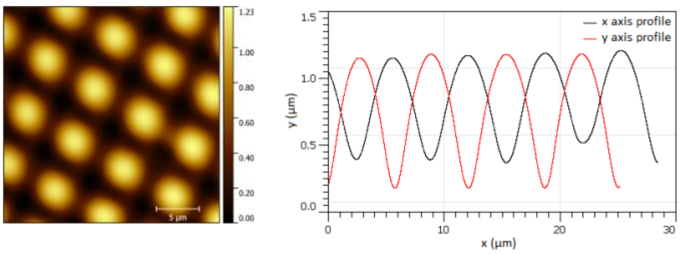


Fig. 4. AFM image and profile of the superimposed diffraction gratings.

AFM image with rectangular regular relief structures of superimposed grating recorded through 2 exposure steps and its diffraction pattern is shown in Fig. 4. The modulation depth of the pattern is 1200 nm estimated from the AFM cross-section profile. The revield induced surface profile shows linear, rectangular and hexagonal surface pattern for the 1-, 2- and 3-fold rotation symmetry gratings.

Conclusions

Thin films of carbazole-based azopolymer Polyepoxypropil carbazole: Disperse Orange were demonstrated to be suitable for direct relief patterning. Various superimposed DG including linear, rectangular and hexagonal relief shapes were recorded using polarization holography (P-P pol. states).

The driving mechanism for photoinduced surface gratings was determined to be mass transfer phenomenon. Two complementary techniques were applied for the surface investigation of the DG. Both revealed the symmetrical structure of the modulated relief. Relief depth of hexagonal grating of the polymer film is 1.2 µm.

Acknowledgment

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References

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