Characterization of polarization holographic gratings obtained on azopolymer thin films by digital holographic microscopy

V. Cazac[1,2], C. Loshmanschii[1], E. Achimova[1], A. Meshalkin[1], V. Abashkin[1], V. Podlipnov[3]

[1]*Institute of Applied Physics of Moldova, Academiei 5, Chisianu, MD2072, Moldova*
[2]*Tampere University, Korkeakoulunkatu 1, Tampere FI-33720, Finland*
[3]*Samara National Research University, Moskovskoye shosse 34a, Samara, Russia, 443086*

Abstract

Polarization diffraction gratings are formed by one-step polarization holographic recording in azopolymer thin films. The evolution of the gratings parameters, such as the modulation of refractive index and relief depth with regard to different exposure dose is analyzed. Phase-shifting digital holographic microscopy is applied for the measurement of the light-induced polarization diffraction gratings. For the accurate hologram acquisition and reconstruction of the complex amplitude transmitted by the gratings, we performed all-optical (without moving components) phase-shifting implemented within in the imaging system of the digital holographic microscope. The experimental measurement results and theoretical predictions were compared and analyzed.

Keywords

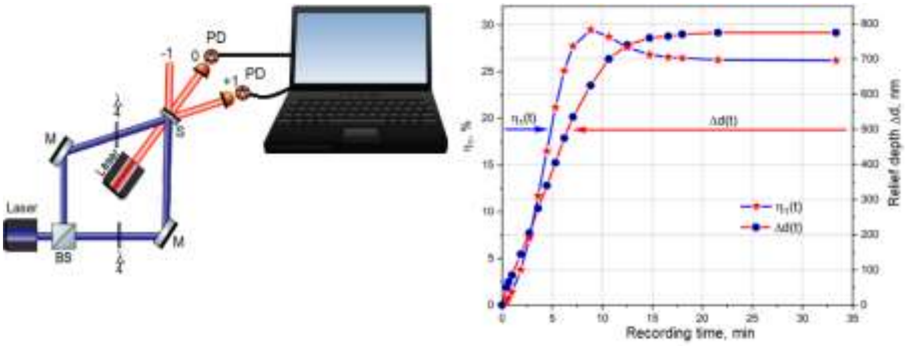
Digital holographic microscopy, polarization holographic gratings, image processing, diffraction efficiency, azopolymer, thin films, phase imaging

1. Introduction

Recently, azobenzene-based photochromic materials have attracted great scientific attention due to the light-induced mass migration, which can be used to create polarization holographic optical elements on thin films as a response to patterned illumination. These materials are particularly intriguing because of the reversibility of the photoinduced changes. Periodic structures created on azopolymer surfaces have many different outstanding applications [1,2]. Interferometry is a flexible approach applied for the creation of complex polarization holographic gratings(PHG) with varying parameters, which would be difficult to create using conventional lithography tools. However, essential understanding and non-destructive observation of light-induced transformations in these materials is crucial and still holds great interest. Digital holographic microscopy (DHM) is a quantitative phase imaging instrument [3], where complex amplitude (amplitude and phase) of light interacting with a sample are measured, by hologram acquisition. The delivered quantitative phase data make interferometric systems the key instrument for 3D investigation of transparent samples such as PHG. In addition, digitalization of the interferograms open the access to the numerical processing of the complex object wavefront for revealing the phase, amplitude and 3D map of the PHG. Optical and physical information about a diffraction grating are encoded in the phase component of the digital hologram. This data permits to calculate and deduce different parameters such as the height and refractive index variations of the recorded optical elements.

In this paper, we introduce phase-shifting DHM for studying PHG recorded on azopolymer thin films. PHG were created under different recording conditions by polarization holographic recording(PHR). The analysis of the dependence of diffraction efficiency on exposure time and relief depth was carried out. The parameters of PHG obtained via phase-shifting DHM permit to extend the understanding of the light-induced topographical patterns (refractive index, surface relief depth) on azomaterial surfaces.

The PHG is obtained by interference of the two waves beams that pass-through quarter waveplates and interfere on the azopolymer thin film (synthesized carbazole-based polymer N-epoxypropylcarbazole and azodye Solvent Yellow 3), as shown in Figure 1(a). The growth kinetics of diffraction efficiency(DE) and relief depth dependence on the exposure time can be observed in Figure 1(b).



a) b)

Figure 1: (a) Polarization holographic recording setup: Laser-single mode DPSS 473 nm(100 mW), BS-polarized beam splitter, M-mirrors, λ/4-quarter wave plate, Laser 650nm, S-azopolymer thin film, PD-photodiodes for DE registration, (b) Dependences of DE and profile depth on the recording time

As it can be seen from Figure 1(b), the maximal DE $\eta \approx 30\%$ is obtained the within 9 minutes, while the highest surface relief depth $\Delta d = 780$ nm achieved within 15 minutes of exposure. The phase-shifting DHM measurements values show slightly different dependence and characteristics of the PHG. Therefore, it is important to take into account all the components that influence optical and physical parameters of the diffraction gratings. These investigations are provided by the implemented phase-shifting DHM obtained under different recording conditions and will be more discussed broadly in the extended paper.

2. Conclusion

In order to realize the full potential of PHG and understand their formation dynamics and response to different exposure doses we used theoretical calculations and experimental measurements using phase-shifting DHM. The comparison between obtained experimental and theoretical parameters of the recorded PHG show particular differences in the relief depth values.

3. Acknowledgements

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4. References

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