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Reflection mode holographic recording in methylene blue-sensitized polyvinyl alcohol acrylamide films

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Abstract. Photopolymer systems can produce good image quality holograms that does not require any post-processing and are environmentally stable with good diffraction efficiency. The present work reports the development of a methylene blue-sensitized polyvinyl alcohol acrylamide (MBPVA/AA) photopolymer system for recording white light reflection holograms. Reflection gratings were recorded in the photopolymer films with different concentrations of methylene blue (MB). Various parameters affecting the holographic properties of the samples were also studied. The holographic performance of the material is found to depend on its chemical composition and the recording parameters.

Keywords. Photopolymers; white light holograms; reflection gratings; holographic data storage.

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1. Introduction

Because of the importance acquired by new technologies (computers and internet), the demand for storage techniques with more capacity, more density and faster read-out rates has increased considerably. Thus, in recent years much attention has been centred on three-dimensional (3D) holographic disks [1,2]. Many recent studies have focussed on the characterization and optimization of thick holographic recording materials in order to obtain maximum data storage capacity [3,4] and transmission holographic memories have been designed [5]. However, in order to obtain more compact systems, it will be interesting to design reflection holographic memories to which the current technology for reading CDs and DVDs (reflective disks) may be applied. Reflection holograms with an acrylamide-based photopolymer have been investigated previously with different compositions of recording material [6]. Such holograms have also been used for different applications such as bit-format holographic data storage [7] and visual indication of environmental humidity [8].

The characteristics of holographic recording material have great effects on the successful applications and the development of holography. Volume phase holograms are used widely for display applications, for cover pages of books, magazines, pop art display, gifts, etc. on account of their attractive designability and decorative effect. Photopolymer has obvious advantages over other photographic emulsions like silver halide as it requires no post-processing. The holograms are viewable immediately and are bright in diffuse light. This makes them very suitable for industrial applications. The reconstruction of holograms using white light sources is completely different from that which uses laser beams. In other words, white light includes the whole spectrum of visible wavelengths and the light sources have finite size.

In this paper we focus on the development of methylene blue-sensitized polyvinyl alcohol acrylamide films for reflection holography. The primary goal of this work was to check the suitability of such a photopolymer for recording reflection holograms and to study its properties under white light.

2. Methodology

The photopolymer system used in this work is one which is developed in our lab [9]. It consists of polyvinyl alcohol (PVA) binder, acrylamide photopolymerizable monomer (AA), triethanolamine (TEA) initiator and methylene blue (MB) photosensitizer dye. The photopolymer films prepared using gravity settling method were allowed to dry at room temperature. Thickness of the dried sample was found to be 130 μm, measured using Dektak Stylus profiler. In order to determine the spectral sensitivity of the developed photopolymer films, absorption spectra were taken using UV–visible–NIR spectrophotometer (Model JASCO V-570) and from the absorption spectra it was found that the material has good absorption at red wavelength region (figure 1). For recording reflection gratings, dried samples were exposed with an interference field as shown in figure 2,

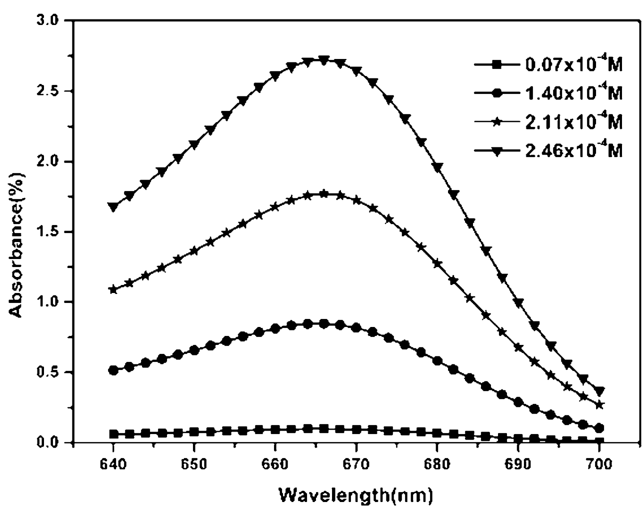

Figure 1. Variation in absorption with dye concentration.

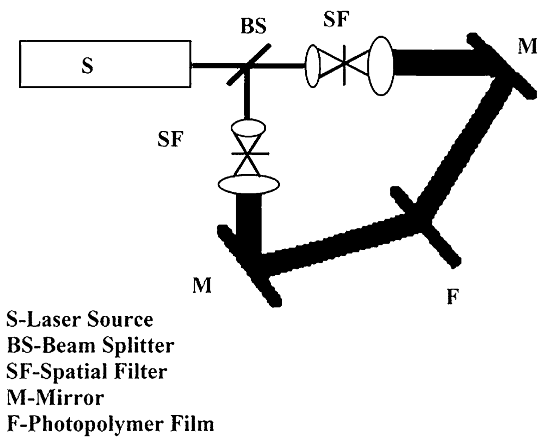

Figure 2. Double beam method for recording reflection gratings.

and the diffraction efficiency (DE) of the formed gratings were measured. The material properties were determined based on diffraction efficiency of the recorded gratings. The diffraction efficiency of the photopolymerizable film depends on the composition of different components and recording conditions. So the composition and conditions should be carefully optimized after a large number of trials. Molarity of the dye was varied from 0.07×10^{-4} M to 2.46×10^{-4} M and gratings were recorded on these samples using He–Ne laser. The variation in DE of the gratings recorded at an angle of 100° with exposure

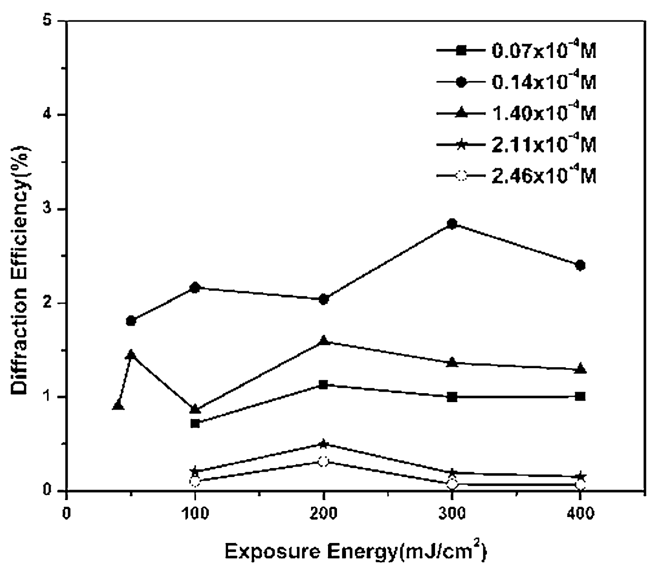

Figure 3. DE vs. exposure energy for an interbeam angle of 100°.

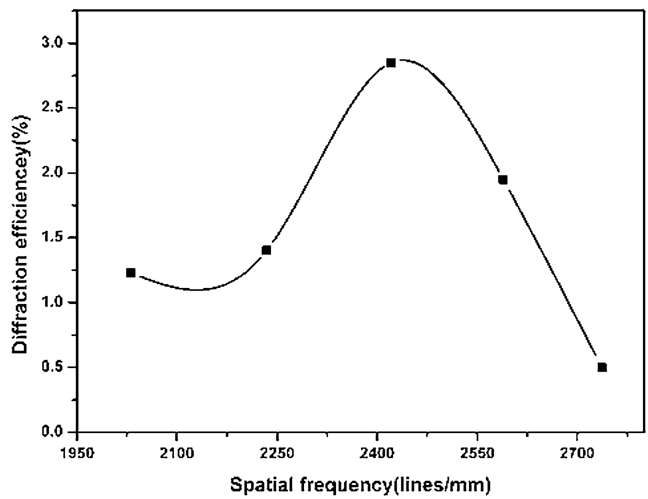

Figure 4. DE vs. spatial frequency of the photopolymer sample.

energy for different concentrations of methylene blue, is plotted in figure 3. The concentrations of all other components were fixed as per our previous work (PVA (10%), AA (0.38 M) and TEA (0.05 M)) [9].

3. Hologram recording

To record reflection hologram the photopolymer should respond well to high spatial frequencies. We can change the spatial frequency of the recorded gratings by varying the recording angle. In this manner, spatial frequency response of the photopolymer sample was studied by recording reflection gratings at an exposure energy of 300 mJ/cm^2 as shown in figure 4. A maximum DE of 2.8% was obtained when the spatial frequency was 2400 lines/mm. Reflection holograms were recorded in the optimized film using He–Ne laser with a standard reflection holographic recording set-up (figure 5). The light emitting from the laser was spatially filtered and collimated. This collimated light was used for

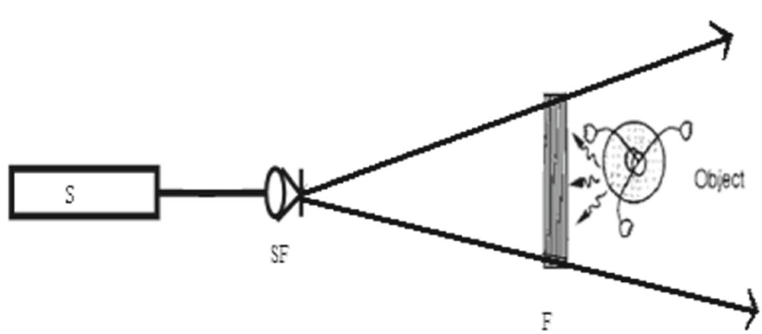

Figure 5. Denisyuk configuration for recording reflection holograms.

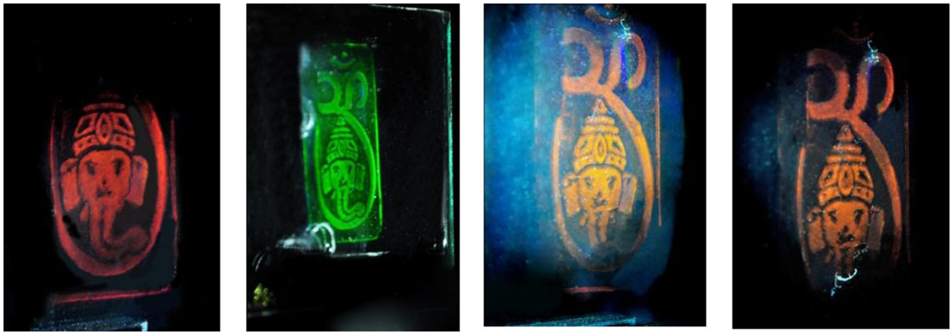

Figure 6. Variation in reflection wavelength with viewing angle.

the illumination of the object placed directly behind the photosensitive medium and acted like a reference beam. This technique of recording reflection hologram is called single beam Denisyuk method. In this technique, the object is illuminated through a holographic plate. The light reflected from the object constitutes the object beam of the hologram. The hologram can be reconstructed in white light.

Before recording reflection holograms, the reflectivity of the object was examined at various distances. For that, He–Ne laser of 15 mW input power was incident over the object. In order to get a feeling of depth in the recorded hologram, the sample was slightly tilted and the distance between the sample and the object varied. Also, the reflected power was measured at distances 0.5 cm, 2 cm and 5 cm. The reflected power decreased with distance. Holograms were recorded at these distances and it was found that the image quality decreased with increase in the distance. Hence the exposure energy was optimized by fixing the distance as 0.5 cm and it was found that an exposure energy 1000 mJ/cm^2 is favourable to capture an image of good quality.

When these reflection holograms were reconstructed using a white light source, it was found that the reflection wavelength changed with the viewing angle, i.e. the object seemed to be in different colours. Figure 6 shows variations in the reflection wavelength with a change in viewing angle.

4. Conclusions

We checked the suitability of MBPVA/AA photopolymer film developed in our lab for recording reflection hologram. A maximum diffraction efficiency of 2.84% was obtained for reflection grating recorded at an angle 100° and exposure energy 300 mJ/cm^2 with MB concentration 0.14×10^{-4} M, on the photopolymer sample of thickness 130 μm. Bright reflection holograms were recorded in these samples. The variation in the quality of image *vis-à-vis* distance was noted from the sample. Variation in the reflection wavelength with viewing angle when this hologram was reconstructed using a white light was also noted.

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References

[1] J R Lawrence, F T O'Neill and J T Sheridan, *Optik* **112**, 449 (2001)
[2] A Pu and D Psaltis, *Appl. Opt.* **35**, 2389 (1996)
[3] M Schnoes, B Ihas, A Hill, L Dhar, D Michaels, S Setthachayanon, G Schomberger and W L Wilson, *Proc. SPIE* **5005**, 29 (2003)
[4] H Coufal, D Psaltis and G T Sincerbox, *Holographic data storage* (Springer-Verlag, 2000)
[5] E Fernández, C García, I Pascual, M Ortuño, S Gallego and A Beléndez, *Appl. Opt.* **45**, 7661 (2006)
[6] R Fuentes, E Fernández, C García, A Beléndez and I Pascual, *Appl. Opt.* **48**, 6553 (2009)
[7] R Jallapuram, I Naydenova, R Howard, S Frohmann, S Orlic and H J Eichler, *Opt. Mat.* **28**, 1329 (2006)
[8] I Naydenova, R Jallapuram, V Toal and S Martin, *Appl. Phys. Lett.* **92**, 031109 (2008)
[9] K P Nimmi, V Pramitha, K Sreekumar, C Sudha Kartha and R Joseph, *J. Appl. Polym. Sci.* **125**, 1238 (2012)