International Journal of
Scientific Research in Science and Technology (IJSRST)
Print ISSN : 2395-6011, Online ISSN : 2395-602X
International Conference on Advanced Materials
Held on 14, 15 December 2017, Organized by Department of Physics,
St. Joseph's College, Trichy, Tamilnadu, India

Investigating the Holographic Performance of a Developed Photopolymer Material by Hologram Recording

C.S. Rajesh[1], P. Safala[1], K. Anjana[1], G. Aswathy[1], C. Sudha Kartha[1]
[1]Department of Physics, CUSAT, Cochin-682 022, Kerala, india
Corresponding Author Email: csk@cusat.ac.in

Abstract

The present work explores the holographic performance of developed eosin sensitized Poly (vinyl alcohol)/Acrylamide based photopolymer material (EPVA) by hologram recording. The developed material can be used to record gratings with diffraction efficiency (DE) of 85% using 488 nm and 77% using 532 nm at exposure of 50 mJ/cm^2. Recorded Fourier Transform (FT) holograms and Projection type holograms showed the potential of this material for different holographic applications.

Keywords: Holography, Photopolymers, Gratings, Holograms.

1. Introduction

Holography is a versatile technology which can satisfy next generation needs since the industry demands cost effective and compact optical systems for data storage, data transfer, artificial intelligence, optical interconnects, display applications etc [i-vi]. In this regard, photopolymer systems have attracted much attention in recent years since they proved to be promising material system for holographic data storage and display applications [i-ii, vi]. Low cost, with excellent performing parameters like high diffraction efficiency, good photosensitivity, large refractive index modulation, high resolution, large dynamic range, made acrylamide based photopolymers to occupy an elevated position in the field of holography [ii,iv-vi]. The potential applications and markets of photopolymers in holography are based on the function of the hologram or diffractive feature (e.g. an image or Holographic Optical Elements) recorded in that material. One of the important properties of photopolymer is the self-processing, which makes them non-amenable to wet processing; a good criteria for holographic data storage, holographic optical elements (HOEs) and display applications [vi].

The present work is an investigation on the suitability of recording different holograms in an already developed Eosin sensitized Poly (vinyl alcohol)/Acrylamide photopolymer (EPVA) films [vii]. Existence of a close experimental relation between holographic data storage and fourier hologram recording methods, decided the priority of this hologram among others. Initially fourier holograms were recorded on the developed EPVA material. Another important class of holograms is 'projection holograms' which are actually hologram of a hologram and can be viewed in white also.

2. Materials and Methods

The photopolymer system used in this work consists of poly (vinyl) alcohol (PVA) - binder), triethanolamine (TEA) - initiator and Yellowish Eosin (EY) - photosensitizer dye and photopolymerizable monomer Acrylamide (AA)[vii]. The photopolymer films prepared using gravity settling method was allowed to dry at room temperature. Using double beam interferometry gratings were recorded on the dried photopolymer films with interbeam angle 40^0 and beam intensity ratio as 1:1. The recorded gratings were reconstructed using a He-Ne laser (Melles Griot - 632.8 nm) and the diffraction efficiency (DE) was determined using the relation,

$$\textbf{DE (\%)} = (I_d/I_i) \times 100$$

I_i-Incident beam intensity, I_d-First order diffracted beam intensity.

3. Results and discussion

3.1. Recording of holographic gratings

Spectral sensitivity of the developed photopolymer films was determined from absorption spectra (taken using JASCO V-570 UV-Visible-NIR spectrophotometer) of the samples. Absorption spectra of unexposed and exposed samples show that this material can respond well to 532 nm and 488 nm wavelengths as shown in Figure 1.

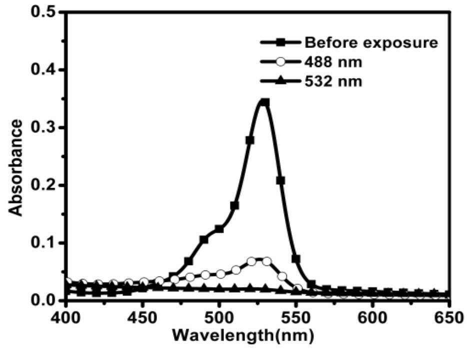

Figure 1. Absorption spectra of exposed and unexposed samples

In the previous work [vii], a DE of 85% at exposure of 50 mJ/cm² was reported using this material. The same material can be used to record gratings using 532 nm laser with DE of 77% at exposure 50 mJ/cm² as shown in Figure 2.

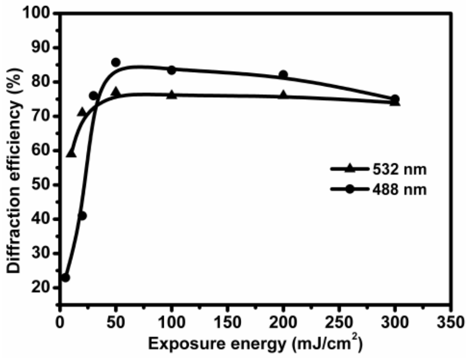

Figure 2. Variation in DE with Exposure energy

The variation in DE with exposure energy was similar to that of 488 nm wavelength laser. The studies revealed that the material shows good holographic performance for two wavelengths 488 nm and 532 nm.

Holographic device working with low power laser can reduce the cost of the system. Hence it is essential to assess the holographic performance of the material at lower laser power also. Figure 3 shows that even with 1 mW power laser, it is possible to record more than 80% DE gratings in this material.

In an interference pattern maximum fringe visibility is possible when the intensity ratio between the interfering beams are at 1:1. In the case of hologram recording, it is difficult to maintain a 1:1 beam ratio between the object and reference beams. So the effect of variation of beam intensity ratio was checked by varying the intensity ratio of interfering beams. From Figure 4 it was seen that even at a beam ratio of 1:0.2 it was possible to record gratings with more than 60% DE.

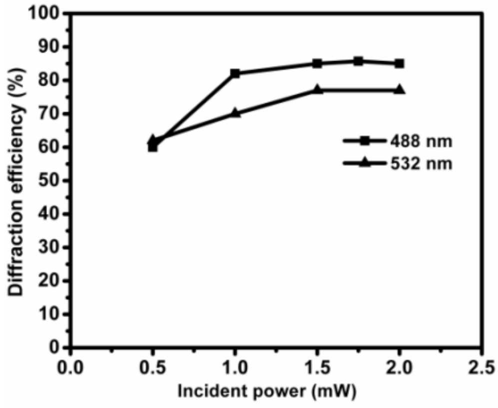

Figure 3. Recording of gratings with different laser

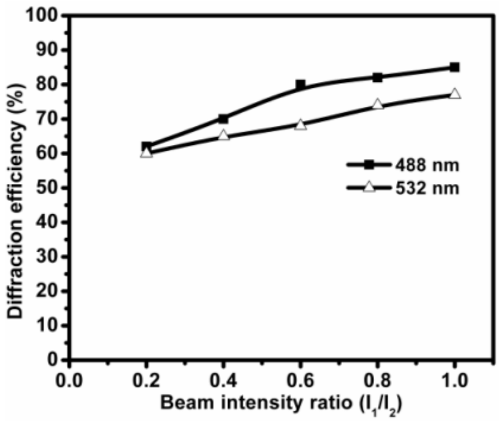

Figure 4. Variation in DE with beam ratio

3.2. Recording of Fourier Transform holograms

Apart from imaging, 'fourier holograms' are also suitable for data storage applications, because in holographic storage devices data pages are recorded using fourier transform (FT) method. Two dimensional holograms can be recorded on the material by consuming minimumsample area and the noise in the image could be reduced by incorporating suitable filters in the fourier plane. Usually, in storage devices the object beam is allowed to pass through a spatial

International Journal of
Scientific Research in Science and Technology (IJSRST)
Print ISSN : 2395-6011, Online ISSN : 2395-602X
International Conference on Advanced Materials
Held on 14, 15 December 2017, Organized by Department of Physics,
St. Joseph's College, Trichy, Tamilnadu, India

light modulator (SLM), but in the present study the object beam was passed through a transparency containing few letters. FT holograms were recorded using the experimental setup illustrated in Figure 5.

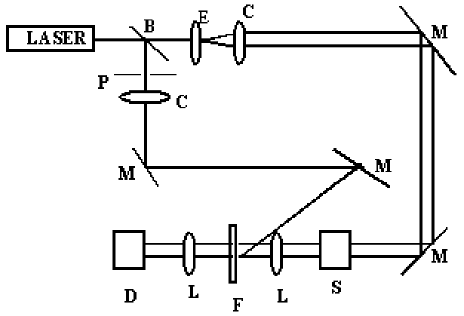

Figure 5. B-beam splitter, E-beam expander with spatial filter, P-Pinhole, C-Collimating lens, M-Mirror, S-Object, L-Lens, F- film, D-Detector

A B C

Figure 6. FT holograms and its reconstructed images

3.3. Recording of projection hologram

Projection holograms also known as standout hologram or as an image-plane hologram provide a dramatic visual with the entire image floating in front of the plate [viii]. For recording projection holograms the object beam used was not coming from a real object, but rather it is light that comes from a 'master hologram' and forms a real image of the object [viii-x].

When the copy hologram is processed, it is illuminated in the usual way for transmission holograms, and as always there will be a virtual image and a real image. With an ordinary hologram the images are well separated and they are not seen simultaneously. With the projection hologram they are both seen, since they are very close together and in fact join at the plate. The observer sees the virtual image behind the plate and the real image in front of the plate. Projection holograms can be used for display purposes as well as for making holographic lenses that can be used as compound lenses along with a real lens [viii].

For recording projection holograms, a master hologram was initially created using transmission geometry as shown in Figure 7 which is also known as Denisyuk method. Figure 8 is the photograph of a hologram recorded and reconstructed using 488 nm laser. This hologram was used as master hologram for producing a real image.

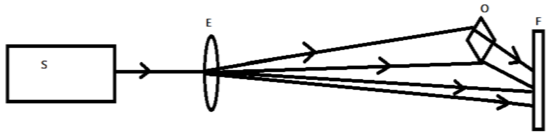

Figure 7. The experimental set up to record Denisyuk hologram; S-laser, E-beam expander with spatial filter, O-object, F-film

Figure 8. Photograph of Denisyuk hologram reconstructed using 488 nm laser

Figure 9 is the experimental setup for recording projection holograms. The master hologram was illuminated in such a way that the hologram is exposed to its conjugate beam giving a real image. This real image is caught on another plate and reference beam will be allowed to fall on the same plate to form a hologram.

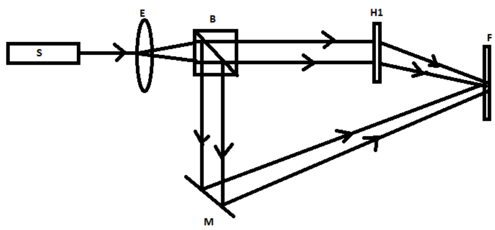

Figure 9. Recording set up for projection hologram;

International Journal of
Scientific Research in Science and Technology (IJSRST)
Print ISSN : 2395-6011, Online ISSN : 2395-602X
International Conference on Advanced Materials
Held on 14, 15 December 2017, Organized by Department of Physics,
St. Joseph's College, Trichy, Tamilnadu, India

S-laser, E-beam expander with spatial filter, B-beam splitter, H1-master hologram, M-mirror, F-polymer film

The photograph of a recorded projection hologram, reconstructed with white light is shown in Figure 10.

Figure 10. Photograph of a projection hologram viewed in white light

3.5. Conclusion

Feasibility study was conducted to assess the holographic performance of the developed eosin doped poly (vinyl alcohol)/acrylamide photopolymer films by recording different holograms. It was possible to record and reconstruct FT holograms successfully in this material. Fourier holograms recorded, ensured the suitability of this material for data storage applications as these type of holograms miniaturize the original size of the object (data) increasing the storage capacity. It was also possible to record 'Projection holograms' in this material, which are actually 'hologram of a hologram', can be viewed with white light in transmission mode also. Thus the developed material can be used for different applications such as data storage applications, HOEs, Display applications etc.

Acknowledgment

One of the authors (CSR) would like to thank UGC for fellowship and the author (CSK) would like to thank KSCSTE for supporting this work through the Emeritus Scientist Scheme.

References

[1] H. J. Coufal, D. Psaltis, and G.T. Sincerbox, Holographic Data Storage, Springer, New York (**2000**).

[2] Toal, V.; Introduction to Holography, CRC Press, Taylor & Francis, New York (2012).

[3] A. Pu, K. Curtis, D. Psaltis, "Exposure Schedule for multiplexing holograms in photopolymer films" Opt. Eng. 35, 2824(1996).

[4] J. Guo, M.R. Gleeson, and J.T. Sheridan, "A Review of the Optimisation of Photopolymer Materials for Holographic Data Storage," Physics Research International, 2012, 803439, (2012).

[5] H. Akbari, I. Naydenova and Suzanne Martin, "Using acrylamide-based photopolymers for fabrication of holographic optical elements in solar energy applications," Appl. Opt. 53, 1343-1353 (2014).

[6] D. Jurbergs, F.K. Bruder, F. Deuber, T. Fäcke, R. Hagen, D.Hönel, Thomas Rölle, M.S. Weiser, A. Volkov, "New recording materials for the holographic industry" Proc. of SPIE Vol. 7233, (2009).

[7] C.S. Rajesh, S.S. Sree Roop, V. Pramitha, Rani Joseph, K. Sreekumar, C. Sudha Kartha, "Study on the performance of eosin-doped poly(vinyl alcohol)/acrylamide photopolymer films for holographic recording using 488-nm wavelength," Opt. Eng.50 (2011).

[8] Joseph E Kasper, The Hologram Book, Prentice-Hall International Inc., New Jersey (1985)

[9] P. Hariharan, Optical Holography - Principles, techniques and applications, Cambridge University press, Cambridge (1984).

[10] Howard M. Smith, Principles of Holography, Wiley-Interscience, U.S.A (1969).