engineering proceedings

Proceeding Paper

Study of a pH-Sensitive Hologram for Biosensing Applications †

Komal Sharma [1,2], Heena [1], Girish C. Mohanta [1,2] and Raj Kumar [1,2,*]

1 CSIR-Central Scientific Instruments Organisation, Sector 30C, Chandigarh 160030, India; komalsharmasharma1998@gmail.com (K.S.); heenakhatri976@gmail.com (H.); gmohanta@csio.res.in (G.C.M.)
2 Academy of Scientific and Innovative Research (AcSIR), Ghaziabad 201002, India
* Correspondence: raj.optics@csio.res.in

† Presented at the International Conference on "Holography Meets Advanced Manufacturing", Online, 20–22 February 2023.

Abstract: Photopolymers are widely utilized as holographic recording media due to their ease of preparation and lack of wet chemistry post-processing. Holographic sensors constructed from a pH-sensitive photopolymer film have several applications in biosensors and the medical diagnostic field. However, the stability of photopolymer films in an aqueous medium is one of the most important challenges in their application for biosensing. Furthermore, the pH of the solution is another important parameter for biochemical reactions. In this work, we compared the pH sensitivity and stability of our holographic grating against two widely utilized classes of buffers; Phosphate Buffered Saline (PBS) and Tris-Acetate-EDTA (TAE) at two different pH values of 7.36 and pH 8.3, respectively. It was observed that a physiological pH (pH 7.4) had a negligible effect on the diffraction efficiency of the holographic sensor while it significantly deteriorated at a higher value of ~pH 8.3. This high sensitivity towards the minute pH difference of our holographic sensor could potentially be exploited for pH-based biosensing applications such as urea detection.

Keywords: holographic sensors; photopolymer film; biosensors; pH-sensing

Citation: Sharma, K.; Heena; Mohanta, G.C.; Kumar, R. Study of a pH-Sensitive Hologram for Biosensing Applications. *Eng. Proc.* **2023**, *34*, 22. https://doi.org/10.3390/HMAM2-14272

Academic Editor: Vijayakumar Anand

Published: 21 March 2023

1. Introduction

The quantitative and qualitative measurement of different physical and chemical processes is very important in the field of medical, agriculture, industrial and environmental applications. Holography is one of the optical techniques in which one can observe physical and chemical changes in the material. It is a method for storing and retrieving object information using light diffraction and interference. This technique uses an object beam and a reference beam that are both captured on the photopolymer film to produce an interference pattern. This technique has the advantage of not needing an additional rechargeable power unit, versatility, robustness and ease of preparation. These benefits led to its use in the field of biosensing applications such as glucose, lactose, pH detection and drug detection, among other things [1]. In order to achieve the necessary results with accuracy, selectivity, and sensing capacity, photopolymer films must be prepared with all points of care, mainly in biosensing applications.

Recently, it has been reported that the polyvinyl alcohol (PVA)-based photopolymer, due to its non-toxicity, swelling properties and good adhesive properties, have been used widely [2]. For biosensing applications such as drug detection and pH sensors, this binder is not desirable due to its hygroscopic nature. Additionally, cellulose acetate-based photopolymers are biocompatible, sustainable, cheap, flexible, lightweight and biodegradable [3] but have limitations in film formation due to the volatile nature of the solvent used.

In this paper, we propose to analyze the effect of pH change on the diffraction efficiency of transmission gratings recorded in a commercially available photopolymer as holographic recording material by dipping it in the buffer solutions for different time intervals. The diffraction efficiency of the recorded grating can be measured as:

$$\text{D.E.}\ (\%) = \frac{I_{D+1}}{I_I} \times 100 \quad (1)$$

where, I_{D+1} and I_I are the intensity of the first-order diffracted beam and incident beam, respectively.

2. Materials and Methods

For biosensing applications, the sensitivity of the material toward pH plays a crucial role. In order to study its effect, changes in the diffraction efficiency of recorded holograms can be calculated at different pH exposure.

2.1. Recording Process

The transmission gratings were recorded in a two-beam holographic optical setup (Figure 1) using a continuous wave DPSS laser (532 nm). The beam was allowed to pass through a spatial filter (S.F.) followed by a lens (L) to obtain a collimated beam which was further divided into two by a beam splitter (B.S.). These two beams were directed by the mirrors M1 and M2 on the recording plate (photopolymer film, LLPF465, Light Logics, Trivandrum, India). This film requires a dosage of 12 mJ/cm^2 at 532 nm wavelength. The angle between the interfering beams was 25°. The intensity of these beams was adjusted to equal values by using a neutral density filter. A shutter was used to control the exposure from the laser, and the total recording intensity and exposure time were 12.8 mJ/cm^2 and 740 ms, respectively. After the recording process, gratings were characterized by a diffraction efficiency measurement (Figure 2) of the first diffracted order using an optical power meter. When the grating is illuminated with white light it diffracts different wavelengths at different angles resulting in a spectrum of colors as seen in Figure 2b.

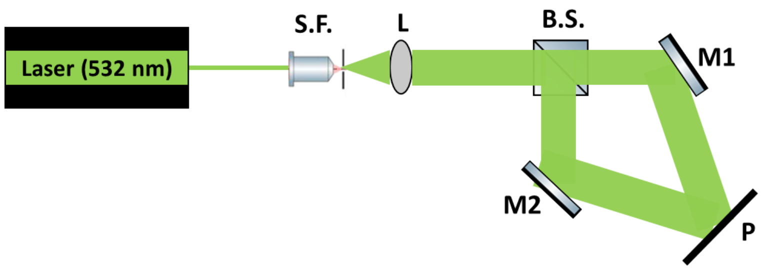


Figure 1. Schematic of experimental setup for recording of transmission gratings.

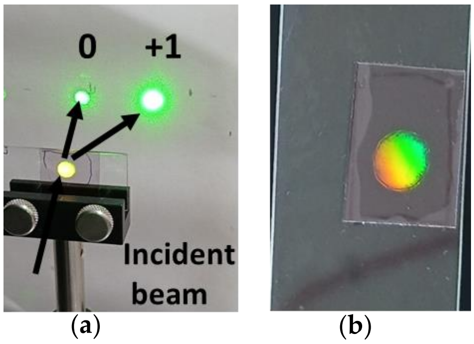


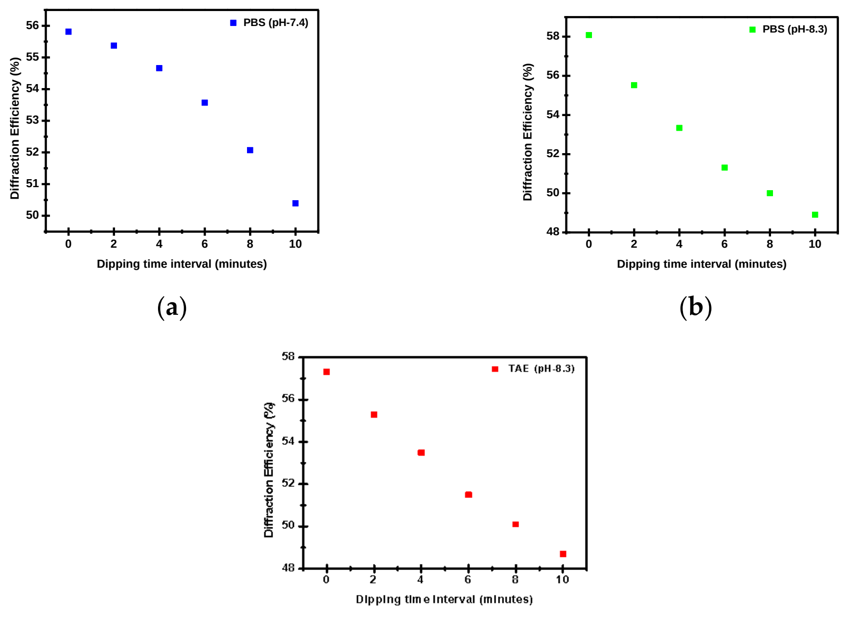
Figure 2. Photograph of (**a**) diffracted orders upon illumination with laser beam and (**b**) grating illuminated with in white light.

2.2. pH Sensitivity Measurement

In order to study the effect of pH sensitivity, three widely used buffer solutions were prepared with different pH values, namely Tris-Acetate-EDTA (pH-8.3) and Phosphate Buffered Saline (pH-7.4 and 8.3). The motive behind using PBS at two different pH levels was to examine the variation in the diffraction efficiency of a hologram with a varying pH of the same solution without relying on the pKa value. The pKa value was used to measure the acidity of a particular molecule in the solvent. Experiments were performed to see the effect on the photopolymer film by varying the pH when these gratings were dipped into different solutions for different time intervals, and a subsequent change in diffraction efficiency was measured. The total volume of the solution was 30 mL for the complete immersion of glass slides.

3. Results and Discussion

The recorded gratings exhibited a diffraction efficiency of >55% before any exposure to the pH solutions. Once these were allowed to completely dip into different pH solutions, a variation in the diffraction efficiency values was observed. The observed change was different for different pH values. For neutral pH, i.e., 7.4, the change in the diffraction efficiency was slight, within 5% of the original values (Figure 3a). On the other hand, when the pH increased to 8.3, the deterioration was much more for both PBS (Figure 3b) and TAE (Figure 3c) solutions, and the percentage change was up to 10% for the given dipping time intervals. From this, we could infer that the recorded holograms showed sensitivity toward alkaline pH and could be used for biosensing applications.



(c)

Figure 3. The diffraction efficiency response with dipping time intervals at different pH: (**a**) PBS pH-7.4; (**b**) PBS pH-8.3; (**c**) TAE pH-8.3.

4. Conclusions

In this work, we recorded holographic transmission gratings in photopolymer recording material and compared the pH sensitivity and stability of our holographic grating against two widely utilized classes of buffers; Phosphate Buffered Saline (PBS) and Tris-Acetate-EDTA (TAE) at two different pH values of 7.36 and pH 8.3, respectively. The sensitivity of the recorded hologram changed with pH, and by increasing its value from 7.4 to 8.3; the variance in diffraction efficiency decreased substantially. This study is helpful in the further development of holographic sensors for the bio-sensing industry, including glucose sensors, urea sensors, lactose sensors, and drug detection sensors.

Author Contributions: K.S.: methodology, formal analysis, writing—original draft preparation, H.: methodology, formal analysis, writing—original draft preparation, R.K.: Conceptualization, supervision, writing—review and editing, project administration, funding acquisition, G.C.M.: writing—co-supervision, review and editing. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Department of Science and Technology, ministry of Science and Technology, India (DST—INSPIRE program, IF-210411) and CSIR funded project MLP-2014.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy and ethical reasons.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Yu, J.; Gai, Z.; Cheng, J.; Du, K.; Wei, W.; Li, Y.; Gao, Q.; Zou, C.; Qian, R.; Sun, Z.; et al. Construction of Beta-Cyclodextrin Modified Holographic Sensor for the Determination of Ibuprofen in Plasma and Urine. *SSRN Electron. J.* **2023**, *385*, 133650. [CrossRef]
2. Gaaz, T.; Sulong, A.; Akhtar, M.; Kadhum, A.; Mohamad, A.; Al-Amiery, A. Properties and Applications of Polyvinyl Alcohol, Halloysite Nanotubes and Their Nanocomposites. *Molecules* **2015**, *20*, 22833–22847. [CrossRef] [PubMed]
3. Gul, S.; Cassidy, J.; Naydenova, I. Water Resistant Cellulose Acetate Based Photopolymer for Recording of Volume Phase Holograms. *Photonics* **2021**, *8*, 329. [CrossRef]