Environmental conditions influence for real-time hologram formation on dichromated polyvinyl alcohol NiCl₂·6H₂O doped films

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Abstract. The real-time holographic gratings recording are studied by the presence of a metallic salt. The experimental process refers to analysis of diffraction efficiency by the influence of humidity in the coating solution on holograms formation in presence of electrical potential. The diffraction efficiency is measured as a function of the exposure energy until reach the saturation. The influence of the hologram parameters to get the diffraction efficiency is studied at room conditions.

1. Introduction

Photopolymers which have been studied previously for conventional imaging applications, exhibit holographic-quality resolution and are self-developing; therefore, they are attractive for these applications [1-3].

When exposed to interfering light beams, as in hologram formation, the systems undergo photopolymerization reactions that encode the fine spatial interference pattern of the incident light [4]. Some researchers have investigated real-time hologram formation in the presence of external electron donors and the influence of humidity on holograms formation [5]. Other researchers studied the influence of pH in the coating solution and the concentration of the dichromate on the photochemical evolution of the intermediates [6]. High relative humidity has been found to significantly improve the photo-speed and the real-time diffraction efficiency [7].

The future of holography is strongly dependent upon the development of new recording media capable of recording gratings of high spatial frequencies, better energy sensitivity, broad wavelength selectivity, involvement of simpler or no processing procedure and erasability [8].

Once the hologram has been recorded, the angular variation of the diffraction efficiency gives a great deal of information about the properties of the material such as thickness, index modulation, scattering and grating profile [9].

The dependence of real time diffraction efficiency of DC-PVA films on the relative environmental humidity has been studied for volume transmission holograms. Some researchers found that in almost all cases studied higher relative humidity affects positively the photoreduction and the subsequent crosslinking in the PVA matrix and, hence, significantly improves the photospeed and real time diffraction efficiency in DC-PVA films with and without electron donors [10].
2. Experimental Method

Polyvinyl alcohol (PVA) solution is doped with potassium dichromate (DCP), nickel (II) chloride hexahydrate (NICHEX) and glycerol to get photosensitive films. This hybrid material does not require chemical or thermal processing and they are not vulnerable to environmental degradation.

2.1. Coating solution and films

The basic solutions are prepared by PVA solution (6.7% p/p), DCP solution (10% p/p) and NICHEX solution (10% p/p). Each solution is stirring, mixing and heating step by step during 45 min to dissolve powder and crystals in aqueous solutions using bi-distilled water. The photosensitive solution was prepared adding 0.5 ml of DCP solution, 0.5 ml of NICHEX solution and 20 µl of glycerol in 3 ml of PVA solution. The mixture was stirred and mixed well to get a homogeneous solution.

The dichromated polyvinyl alcohol nickel (II) chloride hexahydrate solution has been poured on the clean leveled substrate. The substrate used in the experiment is glass (Lauka®). The amount of solution poured on the substrate is 40 µl. The plate area is 56 x 26 mm.

There are different techniques employed to obtain coatings but the gravity settling method has been adopted in this work. After deposition of coating solution on the substrate a cover should be placed above the plate to prevent dust particles from falling on the film until it is dry ~ 24 h later. Two similar plates with the coating solution are used in each case and between both of them there are two copper electrodes like a sandwich. The total thickness of film is 200 µm.

The preparation of coating solution and films are made at room conditions in the laboratory. The photosensitive film is exposed to basic experimental setup of simple two-beam arrangement. The two blue recording beams came from of He-Cd coherent laser at 442 nm. The reading beam came from coherent He-Ne laser at 632.8 nm. The electrical potential source for the experiments reaches a maximum value of 30 Volt. Diffracted beam is measured during hologram formation as a function of the exposure energy with electrical potential application and without it.

3. Results and Discussion

The holographic properties of dichromated polyvinyl alcohol NiCl₂·6H₂O doped films have been studied during real time holographic recording. The holographic curves for the photosensitive films are a function of exposure energy. Table 1 presents environmental conditions for coating solution and experimental setup conditions.

| Table 1. Environmental and experimental setup conditions for each figure. |
|---------------------------------------------------------------|
| Spatial Frequency (lines/mm) | 666 | 666 | 766 | 766 |
| He-Cd Laser Intensity (W/cm²) | 9.71x10⁻³ | 3.20x10⁻³ | 4.14x10⁻³ | 3.95x10⁻³ |
| He-Ne Laser Intensity(W/cm²) | 4.00x10⁻² | 4.56x10⁻² | 4.74x10⁻² | 4.75x10⁻² |
| Temperature (°C) | 23.4 | 23.9 | 21.0 | 20.0 |
| Relative Humidity (%) | 42 | 54 | 62 | 44 |
| pH | 4.86 | 4.85 | 4.88 | 4.84 |

The comparative between figure 1 and figure 2 corresponds to room humidity changes. Both figures are presented at spatial frequency of 666 lines/mm. Figure 1 presents relative humidity of 42% and temperature of 23.4°C and figure 2 shows relative humidity of 54% and temperature of 23.9°C.

The photosensitive material and diffraction efficiencies at real time of hologram formation are affected by humidity conditions. The best diffraction efficiencies for this photosensitive material are achieved when the experiment is carried out at low humidity by electrical potential application (see
figure 1). Otherwise, the highest diffraction efficiencies are achieved when the humidity is high and when it is not applied an electrical potential to the films (see figure 2). The humidity changes modify holographic curve behavior making the diffraction efficiencies are decelerate when the electrical potential is applied (see figure 2).

The comparative between figure 3 and figure 4 corresponds to room humidity changes. Both figures are presented at spatial frequency of 766 lines/mm. Figure 3 presents respectively moisture and temperature value of 62% and of 21.0°C. Figure 4 shows correspondingly moisture and temperature value of 44% and 20.0°C.

The photosensitive material and diffraction efficiencies at real time of hologram formation are affected by humidity conditions. The humidity and spatial frequency has an effect to holographic curve behavior: the diffraction efficiencies decrease when the electrical potential is applied. The saturation to holographic curve without electrical potential is achieved at this exposure energy while holographic curve with electrical potential require more exposure energy to achieve the saturation.
At spatial frequency of 766 lines/mm, films exposed to high humidity environment show higher diffraction efficiency than those exposed at low humidity when this photosensitive material is not in contact with electrical potential. When it is applied an electrical potential to the films the curves are inverted for this spatial frequency.

4. Conclusions

- Energetic sensibility of the material is affected by environmental conditions.
- Diffraction efficiency curve depends on the nature of the photosensitive material and the spatial frequency to holographic recording.
- Electrical potential application increase holographic gratings diffraction efficiencies at optimum room humidity conditions.

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