JOURNAL OF OPTICS. 1999. VOL. 28 NO.3 ➢ Page 103 - 109

INFLUENCE OF SOME DEVELOPING PARAMETERS ON THE DIFFRACTION EFFICIENCY OF DICHROMATED GELATIN HOLOGRAMS.

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(Received December, 18, 1998)

In the present study the transmission holographic gratings were made using non-standard gelatin films in our laboratory. A systematic study was carried out on the effect of pH of 1st developing bath, different water baths an the drying of holograms on the diffraction efficiency of the gratings.

INTRODUCTION

Dichromated Gelatin (DCG) is one of the best suitable recording material for holography, because of its high diffraction efficiency (very close to 100%), high modulation capacity, high signal-to-noise ratio, low noise and good environmental stability with cover plate. It also has a unique property of reproducibility to produce desired characteristics [1,2,3,4]. We studied the sensitometric characteristics i.e the effect of sensitizer concentration and pH on the diffraction efficiency of DCG holograms [5]. Commonly used process or the development of the dichromated gelatin holograms involves a water wash followed by dehydration with isopropyl alcohol. The dehydrated plates are dried in a flow of hot air or in vacuum chamber or baked at high temperatures. The plate developed in this process shows milky white opacity due to the precipitation of the gelatin. To eliminate this effect, the plates are first developed in a mild solution of $(NH_4)_2Cr_2O_7$ (0.5% strength) followed by a treatment in Kodak fixer with hardner before the water wash. These steps help to reduce the unreacted hexavalent choromium ion in the gelatin film to the trivalent chromium [6]. In these studies a nonstandard gelatin films were used. In this paper we present the results obtained by systematic investigations made on the effect of pH of the 1st developing bath i.e. 0.5% $(NH_4)_2Cr_2O_7$, influence of different water baths and the method of drying on the diffraction efficiency of the DCG gratings.

EXPERIMENTAL

a) Chemicals and Instruments used in the experiments

- Photo graphic grade Gelatin, bloom strength 110, supplied by Rallis

India Ltd. Fine chemical division, Ootacamund.

- $(NH_4)Cr_2O_7$, GR grade, content 99%, manufactured by LOBA Cheme, India.
- Argon Ion laser, Luxel 95-2 model USA.
- Power/ Energy meter, Model 1825c with silicon detector Model No. 818SL, NRC, USA, for measuring the exposure energy at 488nm.
- Power meter Model No.: OPM 810, Control Optics USA.
- Digital pH meter manufactured by Systronics India, range 2-14 with resolution 0.01,for measuring the pH of processing solutions.
- Humidity/temperature meter manufactured by L.T. Lutron (Taiwan) Model No. HT3004, range 10% to 95% resolutin 0.1%.
- Kodak general purpose fixer with hardner supplied by Kodak, Bombay.
- Isopropyl alcohol, AR grade manufactured by Ranbaxy, India.
- Liquid Ammonia solution, LR grade manufactured by Ranbaxy, India. for varying the pH of $(NH_4)_2Cr_2O_7$ solution.

b) Preparation of gelatin films

18gm of Gelatin was weighed, swelled in 100ml deionised water for 10min and then dissolved in 50°C. The gelatin suspension is coated on 20mm x 25mm glass plates with doctor's blade (Skin grafting blade) method. The thickness of the gelatin films in this study was 26 μm. The required initial hardening of the gelatin film was obtained by adding 0.5% $(NH_4)_2Cr_2O_7$ (by weight of the gelatin) to the gelatin suspension and baking at 150°C for 2 hrs after drying the plates overnight.

c) Sensitization

The plates are sensitized by immersing in 10% $(NH_4)_2Cr_2O_7$ solution with a pH value of 6.2 for 5min at room temperature. Then the plates were kept out side at angle of ~10° for about 3min to allow the excess of ammonium dichromate to runoff. The residue at the edge and the bottom side of the plate is removed with tissue paper and they were baked for 10 min at 80°C.

d) Exposure

The DCG plates were exposed by using 488 nm line of a 2W Ar-Ion laser. The whole experimental setup used for recording dichromated gelatin holograms on a vibration free table. The laser beam was divided into two coherent beams by using a circular gradient beam splitter. These beams were passed through spatial filters consisting of 10X-microscope ojectives and 15μm pinhole apertures and collimated by passing them through the collimating lenses of each of focal length 10.2cm. The interference pattern produced by two collimated laser beams was recorded on the sensitized plate. Intensity of the recording beams was measured by using power/energy meter with silicon detector having an active area of 1sq.cm The power meter reading at the plane of recording multiplied by the time of exposure gives the exposure energy. The angle between the two beams was kept at 40^0 and the normal to the surface of the recording medium bisects this angle. The fringe spacing, Λ=0.713 μm was calculated from the formula $\Lambda=\lambda/2\ \mathrm{Sin}\theta$, where λ = wave length of recording light. θ = half of the angle between the beams. The Q-factor, which distinguished the regime of operaton, is given by [7].

$$Q = 2\pi\lambda d / n_0\Lambda^2 \qquad (1)$$

where d is the thikness of recording medium. The volume phase holograms were recorded by keeping the Q factor greater than 10. In our case it was kept at 103 for $\lambda = 0.488$ μm, d = 26μm, $n_0 = 1.52$ and Λ = 0.713 μm. The value of this Q factor is kept constant throughout the study. The frequency of the grating recorded was 1400 lines/mm.

e) Development

DCG holograms were developed by following method, first they soaked in 0.5% of ammonium dichromate for 5min. followed by soaking in Kodak general purpose fixer with hardner for 10 min. and washed in deionised water for 10 min. Then the plates were dehydrated with 50% isopropyl alcohal for 5 min. and 100% isopropyl alcohol for 5 min. The above process were conducted under room temparature. Then plates were kept in 100% isopropyl alcohal bath at 60^0C for 1min. and the plates were drawn slowly out of the bath and dried with a stream of hot air directed at the liquid gelatin interface.

f) Measurement of defraction efficiency (DE) :

The diffraction efficiency measurements were made by mounting the grating samples on a rotation stage and by passing a light beam from a 632.8 nm He-Ne laser, a wavelength different from the recording wavelength. Intensities of diffracted and zero order beams were measured by using power meter. Diffraction efficiency (DE), η was calculated by using the formula

$$\eta = I_1 / I_T \text{ ....(2)}$$

where I_1 is the intensity of the 1st order diffracted beam and I_T is the intensity of the total transmitted light.

RESULTS AD DISCUSSION :

The most critical step is producing the high difraction efficiency and low noise holograms in dicromated gelatin is the 'developing step'. It is mainly divided in to two steps, water wash followed by dehydration with isopropyl alcohal. The dehydrated plates are dried in flow of hot air or in vaccum chamber or backed at high temparatures.

To study the effect of pH of 1[st] developing bath on the DE of DCG holograms, the pH of 0.5% ammonium dicrhomate solution was varied. In these studies the pH was varied from 4.23 to 9 by adding the required ammount of the 25% ammonium solution to the 0.5% ammonium dichromate solution to change the solution from acid to alkaline. Number of gratings were recorded in DCG by exposing them to fixed exposure energy of 80mj/cm^2. The holograms were developed in different pH values of the 1st developing bath each hologram corresponds to a particular pH value. During the course of the study the room temparature is fluctuated from 26^{0}C to 30^{0}C and the relative humidity is changed from 55 to 70. The defraction efficiency of each hologram was measured. The fig. 1 and fig. 2 shows the results obtained in two different days with a gap of one week. The variation in DE is due to the flutuations in the environmental condition. From these experiments it is found that the optimum pH value of the 1st developing bath i.e. is 0.5% ammoium dichromate is arround 6.0 to obtain maximum difraction efficiency.

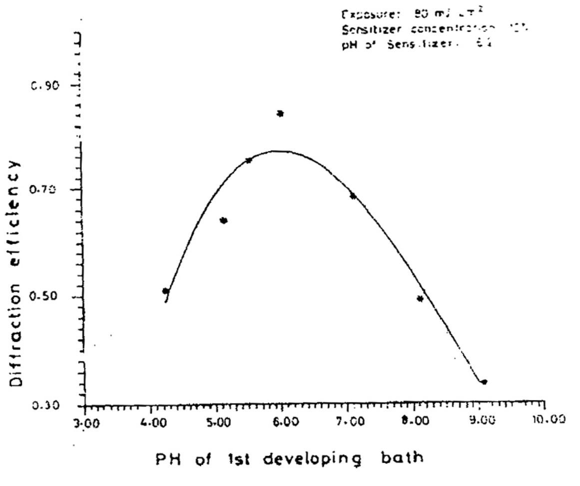

Fig.1 Diffraction efficiency Vs pH of 1st developing bath Solid curve shows the cubic polynomial cure fit.

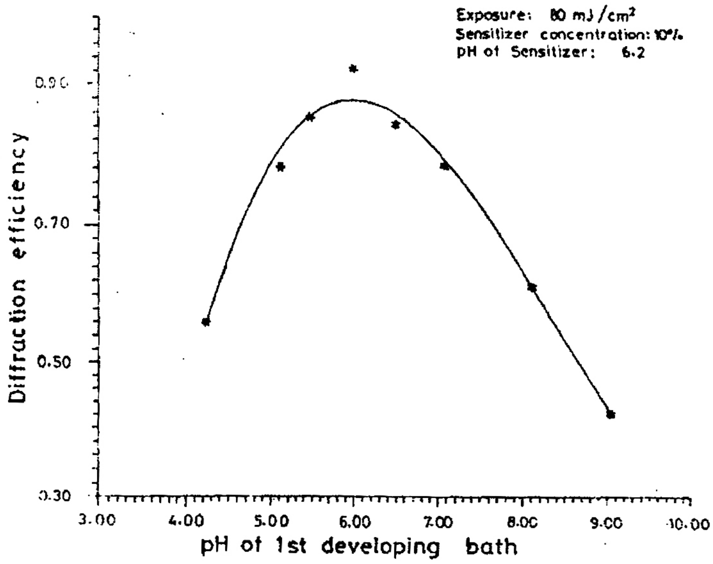

Fig.2 Diffraction efficiency Vs pH of 1st developing bath repeated after one week Solid curve shows the cubic polynomial curbe fit

The influence of the water bath on the diffraction efficiency of the DCG holograms were studied by developing the holograms in different water baths. The results were as shown in fig. 3. It shows that the deionized water and distilled water wash gives the more or less the same diffraction efficiency.Tap water wash produced very low diffraction efficiency as the pH of the tap water is high.

In drying step, the plates are also dried by baking the dehydrated plates at a temparature of 80°C for 10 min. The variation of DE with exposure, for the plates are dried in flow of hot air and backed at high temparature were as shown in the fig.4. The results indicate that the DE is low for the plates dried by baking at high temparatures compared to the plates dried in flow of hot air.

CONCLUSION

In this work the effect of pH of 1st developing bath, influence of different water baths and the process of drying on the defraction efficiency of dichromated gelatin transmission holograms made in nonstandard gelatin films were studied. It was found that the optimum pH value for the 1st developing bath is arround 6.0 and the distilled water or deionised water wash gives the maximum DE. In drying step the plates dried with a hot air directed at the interface of the liquid gives the high DE than compared with the plates dried by baking. These studies help in development of more efficient HOEs.

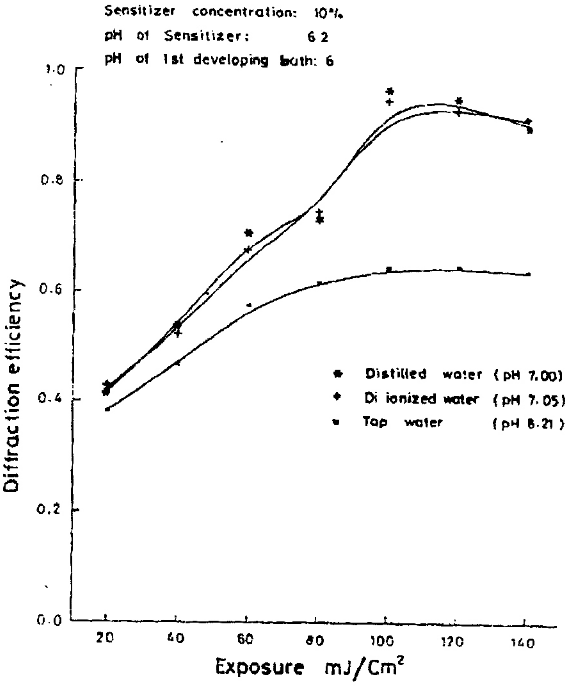

Fig.3 Diffraction efficiency Vs Exposure for different developing water baths.

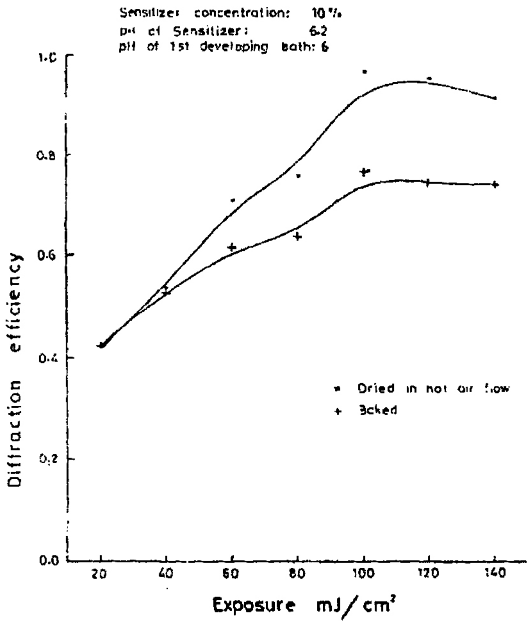

Fig.3 Diffraction efficiency Vs Exposure for different Drying methods.

ACKNOWLEDGEMENT

The authors acknowledge the financial support extended by Department of Science and Technology (DST), New Delhi in the form of research project. The authors sincerely thank C. Prasad, Science Asst. for assisting at various stages of experimental work.

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