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EFFECT OF SENSITIZER CONCENTRATION AND pH ON THE DIFFRACTION EFFICIENCY OF DCG HOLOGRAM

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In the present study, transmission gratings were made using nonstandard gelatin films prepared in our laboratory . A systematic study was carried out on the effect of concentration and pH of ammonium dichromate sensitizer on diffraction efficiency of the gratings.

1. INTRODUCTION

Dichromated gelatin is one of the excellent recording material for recording holographic optical elements (HOEs). It has high diffraction / reflection efficiency, high resolution capacity, high signal to - noise - ratio and good environmental stability with cover plates. In addition DCG has a unique property of reproducibility to produce desired characteristics [1]. It can be used for recording both transmission [2,3] and reflection type [4,5] holographic optical elements. Holographic sensitivity of the DCG depends on the recording wavelength, type of the dichromate salt used for sensitizatio, degree of initial hardness of the gelatin film, processing parameters, and processing environment [6,7]. Among the common salts, ammonium dichromate $\{(NH_4)_2Cr_2O_7\}$ gives higher sensitivity than $K_2Cr_2O_7$ or $Na_2Cr_2O_7$. The sensitivity can be increased about three times by using pyridine dichromate but the shelf life of the sensitized film is only few hours.

In this paper we presented the results obtained by systematic study on the effect of concentration and pH of the sensitizer i.e ammonium dichromate on the diffraction efficiency of volume holographic gratings recorder in dichromated gelatin. So far most of the studies were carried out using the standard gelatin films on commercially available photographic plates (Kodak 649F) from which the silver halide was removed. In these studies a nostandard gelatin film used for the study dependence of diffraction efficiency on the concentration and pH of the ammonium dichromate sensitizer.

2. EXPERIMENTAL WORK :

2.1 Preparation of gelatin plates

The gelatin used in the present study was a non-standard gelatin manufactured by KIND & KNOX Gelatin Inc. USA (T-7877 Photographic grade lot 1, PO.:970107). The coating of gelatin plates done by the doctor's blade (Skin grafting blade) method. The thickness of the DCG film was measured with a Mitutoyo thickness measuring gauge (model No.2109-10) having a least count of 1µm. The thickness was kept under good control(26µm) by fixed wt/vol. of gelatin and deionised water and fixed gap between glass plate and doctor's blade. The initial hardening was done by adding 0.5%(weight of gelatin) of ammonium dichromate to the gelatin suspension and baking at 150^0C for 2hr., after drying the coated plates overnight.

2.2 Sensitization

The Plates were sensitized by immersing in X% of Ammonium dichromate (GR grade LOBA cheme, India) solution for 5 min. After removing from solution, they are kept at an inclination of $\sim 10^0$ to allow the excess solution to run off (about 3 min.). The residue at the edge and glass side of the plate removed with tissue paper and the plates were baked for 10 min. at 80^0 C.

2.3 Exposure

The DCG plates were exposed by using 488 nm line of a Lexel 95 model Ar-Ion laser. The whole experimental setup as shown in fig.1 is kept on a vibration

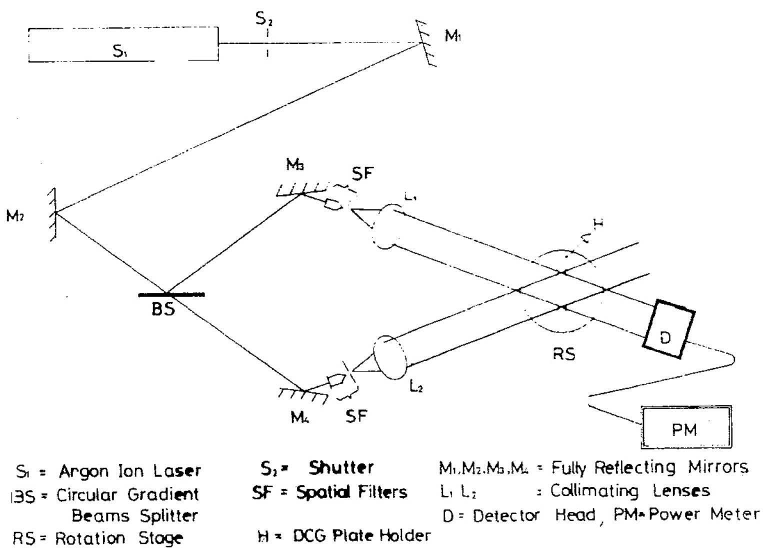

Fig. 1 Expermental setup for recording of DCG holographic gratings.

free optical table made by Newport Corpn. USA. The interference pattern produced by two collimated laser beams was recorded in an area of 1 sq cm. 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, $\Lambda = 0.713 \mu m$ is calculated from formula $\Lambda = \lambda / 2\sin\theta$ where λ = wave length of recording light, θ=half of the angle between the beams. The Q-factor which distinguishes the regime of operation is given by [8].

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

where λ =wavelength of recording light, d= thickness of recording medium, and Λ= fringe spacing. The Q value is 103 calculated by taking $\lambda = 0.488$ µm, d = 26 µm, $n_0 = 1.52$ and Λ=0.713 µm. The value of Q factor is kept constant throughout the study. The beam ratio or the K ratio as defined by $K = I_r/I_o$ is kept as unity. Intensity of the recording beam is measured by using Newport power/energy meter (Model No.1825C) with silicon detector (Model No. 818 SL) having an active area of 1 sq.cm. The power meter reading multiplied by the time of expouser gives the energy.

2.4 Development

After the exposure, the plates were soaked in 0.5% Ammonium dichromate for 5 min. followed by Kodak general purpose fixer with hardener for 10 min., and washed for 10 min. in deionised water. Then the plates were dehydrated in 50% isopropy 1 alcohol for 5min. and 100% isopropy 1 alcohol for 5 min. (Iso-propyl alcohol AR grade, manufactured by Ranbaxy INDIA). The above processes were conducted under room temperature. Then the plates were kept in 60^0C isopropyl alcohol bath for 1 min. and plates were slowly drawn out of the bath and dried with a stream of hot air directed at the liquid interface.

2.5 Measurement of diffraction 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 wave length. Intensities of diffracted and zero order beams were measured by using Control Optics power meter (Model No.: OPM 810). The Diffraction efficiency (DE), η is calculated by using the formula

$$\eta = I_1 / I_T \qquad (2)$$

where I_1 is the intensity of the 1st order diffracted beam and I_T is the intensity of the total transmitted light. Since we are recording in the Bragg regime only one diffraction order besides the zero order is present.

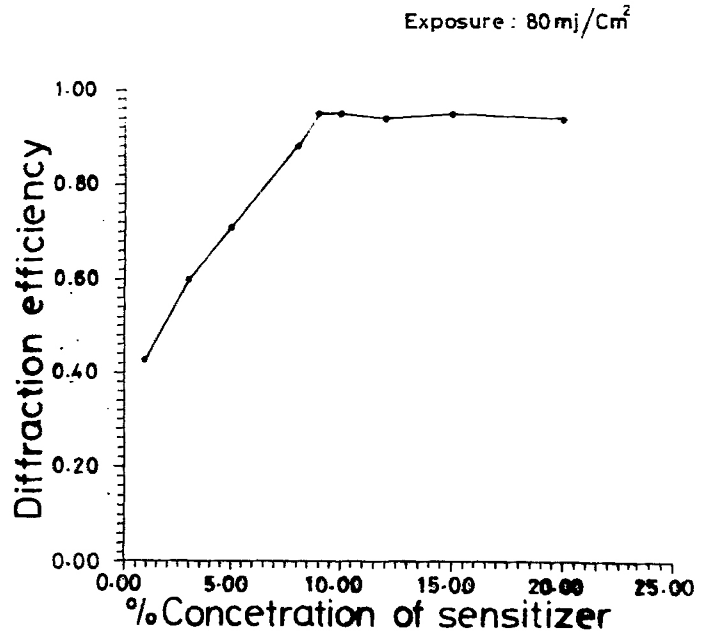

Fig. 2 Diffraction efficiency vs concentration of Ammonium dichromate sensitizer

3. RESULTS AND DISCUSSION

In our study the concentration of the ammonium dichromate (pH = 4.76) is varied from 1% to 20% at a fixed prehardness. The dependence of diffraction efficiency on the sensitizer concentration is as shown in fig.2. The concentration is varied from 1% to 20% at an exposure energy of 100 mJ/cm^2. The points represent the average value of the measurements taken on four different days and the variation in diffraction efficiency is due to small changes in environmental conditions. The result shows that the diffraction efficiency (refractive index modulation) mainly depend on the sensitizer concentration. At lower concentrations (i.e.<10%) DE is linear with the concentration. The diffraction efficiency reached maximum (near 95%) at the sensitizer concentration of 9% and as the concentration increases it remained almost constant. Higher dichromate concentrations (>20%) have resulted in crystallization of dichromate.

To study the effect of pH of sensitizer i.e. ammonium dichromate on the diffraction efficiency, the pH of the ammonium dichromate solution is varied by adding required amount of 25% ammonia solution (AR grade, manufactured by Ranbaxy India) to change the solution from acid to alkaline. In our study the pH range is varied from 4.76 to 9.00. Seven gratings each corresesoonding to a par-

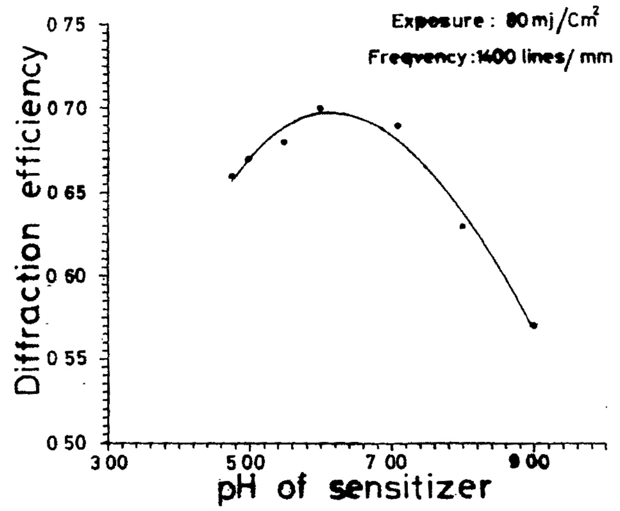

Fig. 3 Diffraction effeciency vs pH of Ammonium dichromate sensitizer in DCG holographic grating recorded on 20-4-1998. Solid curve shows the cubic polynomial curve fit.

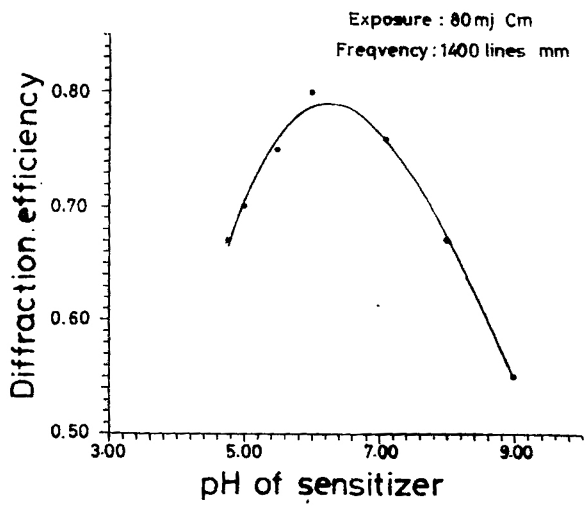

Fig. 4 Diffraction efficiency vs pH of Ammonium dichromate sensitizer in DCG holographic grating recorded on 28-4-1998. solid curve shows the cubic polynomial curve fit.

ticular value of pH of the sensitizer (Concentration 10% kept constant through out the study) were recorded with exposure of 80 mJ/cm^2. During the course of study the room temperature fluctuated from 27^{0}C to 30^{0}C and the relative humidity changed from 55 to 70. Humidity and temperature were measured using Lutron humidity / temperature, meter Taiwan make. The results on two different days with a gap of one week are shown in fig. 3 and fig. 4 . The variation in the DE is due to the variation of temperature and humidity. From this experimental data, it was found that the optimum pH value is around 6.2 to attain maximum diffraction efficiency.

4. CONCLUSION

In this work, effect of sensitizer concentration and pH on diffraction efficiency of DCG transmission holograms made in nonstandard films were studied. Control of concetration and pH of sensitizer resulted in high diffraction efficiency holograns. These studies help in the developement of more efficient HOEs.

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