홀로그래픽 광학소자 제작을 위한 dichromated gelatin 연구

A Study on Dichromated Gelatin for Recording of HOE

Man Ho Jeong*, In Won Lee

Optics Laboratory
Korea Standards Research Institute

ABSTRACT

A method for fabrication of holographic optical elements (HOE) using dichromated gelatin (DCG) as a recording material is presented. We describe the holographic properties of the DCG and the processing techniques. Holographic characteristics of the DCG including exposure characteristics, diffraction efficiency and angular sensitivity are also discussed. The diffraction efficiency of the obtained holographic grating is about 84%.

1. Introduction

Recently there has been extensive invesitigations on recording materials for HOEs. In order to select a suitable recording material for the fabrication of a good HOE we must consider, holographic parameters such as diffraction efficiency, angular and spectral sensitivities and environmental stability. Silver halide gelatin, photoresist and DCG have been used for recording holograms.

Silver halide gelatin holograms have high diffraction efficiency (> 80 %) and are easy to record and process [1-3]. However, silver halide gelatin holograms show relatively high scattering noise and are darkened by extensive light sources. Photoresist is another good recording material for the fabrication of HOEs because of its high diffraction efficiency (> 85%) and good scattering and environmental properties [4-6]. Although properly blazed protoresist grating has efficient properties, it is usually difficult to produce such holograms.

Extensive studies on recording materials for the fabrication of HOEs have shown that DCG is the best material today because of its moderate exposure level, high diffraction efficiency (> 85%), good scattering property and good environmental stability [7,8]. In addition, DCG can be reprocessed to obtained desired holograms.

In this paper we describe a simplified method for making highly efficient DCG HOEs. Basic properties, hologram formation and processing techniques of DCG will be discussed.

2. Basic Characteristics of DCG

The type of DCG hologram is primarily determined by the initial bias hardness of the DCG. Therefore, in order to create volume holograms in DCG, the initial bias hardness of the DCG must be controlled. If the initial hardness is too high, the refractive-index modulation capability will be reduced. On the other hand, if it is too low, the gelatin will be partially dissolved in the development bath and holograms of noisy and low diffraction efficiency will be obtained.

The main function of the preprocessing of the gelatin is to create the proper initial hardness of the gelatin. During the development process, we can also control the hardness of the gelatin, and finally desired refractive-index modulation can be obtained.

The degree of hardness of the gelatin layer can be measured by swelling. The swelling factor is expressed as a percentage increase in weight.[10]

$$k = (W - W_o)/W_o \ \% \qquad (1)$$

where W_o is the weight of the dry film, and W is that of the film with a swollen gelatin layer. The refractive-index modulation Δn is determined by the hardness differential between the exposed and unexposed region. The diffraction efficiency η can be expressed

$$\eta = \sin^2\left(\frac{\pi \Delta n d}{\lambda \cos \theta}\right) \qquad (2)$$

where d is the gelatin thickness, θ is the Bragg angle and λ is the wavelength

If a gelatin film, sensitized with ammonium dichromate solution is exposed to radiation, the hexavalent chromium ion Cr^{6+} is photoinduced to trivalent Cr^{3+}. The cromic ion Cr^{3+} is thought to form a cross-link bond between neighboring gelatin molecules. This cross-link hardens the gelatin creating a hardness difference between the exposed regions and unexposed regions, and this hardness difference forms the latent image of the hologram. During the following development process, the residual chemical compounds remained in gelatin are removed, and the gelatin film swells to a significant extent. In the exposed region, much less water is absorbed than in the unexposed region because of the hardened gelatin.

3. Experimental

To study the effects of various parameters and exposure characteristics on the DCG, transmission holographic gratings with spatial frequency of 1200 lines/mm were recorded at a wavelength of 488 nm on Kodak 649F gelatin layers. The Kodak 649F plates has an initial thickness of 15 μm, but the final hologram thickness varies according to the processing parameters.

The Kodak 649F plates were soaked in fixer with standard hardner concentration (3.25%) and washed in running water for 10 min. This preprocessing step is necessary for removal of silver halide in plate and for initial hardness of gelatin. For sensitization we soaked the gelatin plates in 10% ammonium dichromate solution and bake for 10 min at 80 °C. After exposure the plates were soaked in 0.5% solution of ammonium dichromate, and again in fixer with standard hardner concentration. For development we washed the plates in running water for 10 min and dehydrated in isoprophanol. The simplified DCG holographic process based on the use of Kodak 649F plates is given in Table I.

Table I. Fabrication Procedures of DCG HOEs with Kodak 649F Plates.

1. Soak in fixer with standard hardner concentration (3.25%) for 10 min.
2. Wash in running water for 10 min.
3. Soak in 10% ammonium dichromate solution for 5 min
4. Bake for 10 min at 80 °C.
5. Exposure
6. Soak in 0.5% solution of ammonium dichromate for 5 min.
7. Soak in fixer with standard hardner concentration for 10 min.
8. Wash in running water for 10 min.
9. Dehydrate in isopropanol for 5 min.
10. Bake for 10 min at 80 °C.

4. Results and Discussion

The diffraction efficiency η of the obtained grating is defined as the ratio of the power diffracted in the first order to the incident power excluding the losses due to the reflectiion at the two surfaces of the grating. Fig. 1 shows the diffraction efficiency vs various exposure. The efficiency reaches a high value of 84% at an exposure level of ~170 mJ/cm^2.

Fig. 2 shows the spectral and angular sensitivity of the fabricated holographic gratings. The prominent lines in Ar+ laser (488,514.5 nm) and He-Ne laser line (632.8 nm) are used for this spectral results. It can be observed that the diffraction efficiency decreases with the increase of the wavelength.

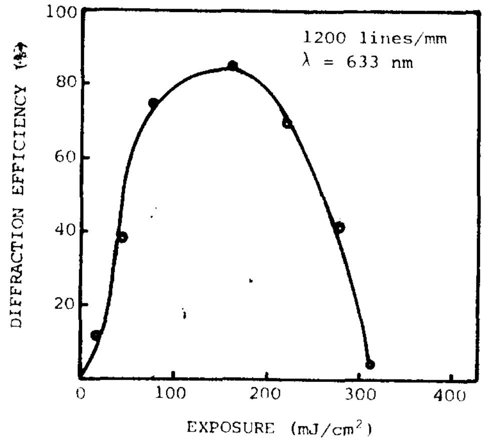

Fig. 1. Diffraction efficiency of the DCG grating vs exposure.

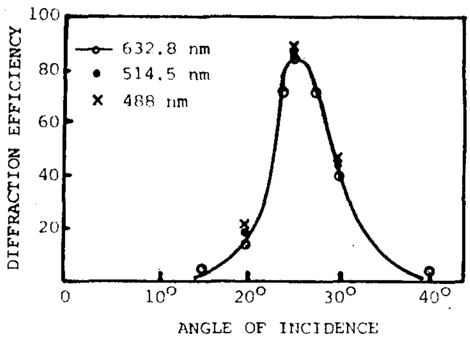

Fig. 2. Spectral and angular sensitivity of the DCG grating.

5. Conclusions

When holograms are used as practical HOEs, several holographic parameters such as diffraction efficiency, angular and spectral sensitivity, scattering noise and environmental stability must be considered. We showed that DCG is good material for the fabrication of HOEs because of its efficient holographic properties. To obtain high diffraction efficiency, it is very important to control the swelling factor. We will further study the control of swelling factor in processing steps of development.

References

[1] R.R.A. Sums and L. Solymar, Appl. Opt., 22, 1479 (1983).
[2] P. Hariharan, Opt. Commun., 56, 318 (1986)
[3] M.H. Jeong and I.W. Lee, New Physics, 28, 327 (1988).
[4] M.J. Beesley and J.G. Castledine, Appl. Opt., 9, 2720 (1970).
[5] M.G. Moharam, T.K. Gaylord, G.T. Sincerbox, H. Werlich, and B. Yung, Appl. Opt., 23, 3214 (1984).
[6] M.H. Jeong, I.W. Lee, M. Park, and S.B. Lee, J. Korea Institute of Telematics and Electronics, 24, 868 (1987).
[7] A. Graube, Opt. Commun., 8, 251 (1973).
[8] T.A. Shankoff, Appl. Opt., 7, 2101 (1968).
[9] B.J. Chang, Opt. Commun., 17, 270 (1976).
[10] B.J. Chang and C.D. Leonard, Appl. Opt., 18, 2407 (1979).