Optica Applicata, Vol. XXI, No. 3, 1991

Reflection holographic optical elements in silver halide sensitized gelatin*

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Silver halide sensitized gelatin has proved to be an alternative to dichromated gelatin as a recording material in the production of transmission holographic optical elements (HOEs). In this paper, we will discuss the possible applications of this process to the production of reflection HOEs.

1. Introduction

Silver halide sensitized gelatins (SHSG) have proven to be a good alternative to dichromated gelatins (DCG) in the production of transmission holographic optical elements. Their high energy sensitivity together with their chromatic sensitivity (based on the spectral response of the photographic emulsions which form the base of the process) make it possible to obtain these HOEs in any part of the visible spectrum [1].

Nevertheless, SHSG possess the same spatial response as the photographic emulsions used at the outset and this makes it difficult to obtain high diffraction efficiency when the spatial frequency is more than 4000 lines/mm, that is, when we want to obtain reflective HOEs.

In this paper, we offer the optimization of SHSG processing with the goal of obtaining good results in reflective HOEs.

The second part of this paper is dedicated to the processing itself and its optimization. We present the process for making a holographic interferential filter and its holographic characteristics.

2. Optimization of SHSG processing

The processing of silver halide sensitized gelatin is a photochemical process that transforms the index modulation that is obtained in an R–10 rehalogenation bleach into an index modulation due to variations in hardening such as the ones produced when using dichromated gelatins. Therefore, this process consists of two stages: the

* This work was presented at the International Colloquium on Diffractive Optical Elements DOE'91, May 14–17, 1991, Szklarska Poręba, Poland.

first is a bleaching process that takes place after fixing, and the second corresponds to a subsequent amplification done with alcohol baths, which permits an index modulation similar to the one obtained in dichromated gelatin with differential hardening.

The basis of optimization of this differential hardening is found in the optimization of the base hardening of the photographic emulsion used in the process. The hardening of the gelatin layer can be measured by the swelling factor. The swelling factor is expressed as a percent increase in weight $(W-W_0)/W_0$, %, where W_0 is the weight of the dry film, and W is the weight of the swelled film. W is determined after swelling in distilled water at 18°C for 15 minutes [2].

In experimental tests using this gelatin with Agfa–Gevaert 8E78 HD plates, swelling factor was measured at 140, which, from a dichromated gelatin point of view, is not acceptable and therefore needs modification. In Table 1 we show

Table 1. Preprocessing schedule for Agfa–Gevaert 8E75 HD plates

Step
1. Bathe in sodium sulphite 1% and urea 5% (in weight) for 10 minutes at 30°C
2. Rinse in running water for 1 minute
3. Dry (20°C and 60% RH) for more than 24 hours

a preprocessing which allows us to modify this swelling parameter. Once the plate is preprocessed using this method, we obtain a swelling factor of 200 which also allows us to achieve high diffraction efficiencies.

One of the most important steps in the processing is the bleaching bath. In our study, we have used a modified R–10 solution made up of potassium bromide, sulfuric acid and potassium dichromate. The effect of bromide on the average life span of the chromium ions is fundamental, because not only does it control its behaviour in the exposed emulsion zones, but it also allows us to modify the degree of hardening of these zones, thereby allowing us to obtain high refraction index modulation.

The developer used, PAAP, is commonly cited in the literature and allows us to obtain low noise levels [3]. The rest of the processing is similar to dichromated gelatin processing and is described in detail in Tab. 2. The adjustment of the bleaching concentrations is fundamental not only for optimizing the diffraction efficiency but also for controlling the wavelength in the reconstruction of reflective HOEs.

Reflective diffraction gratings were made using off-axis geometry at an in-air beam angle of 150°. The illumination source used was a 15 mW He-Ne laser. The gratings were measured with an Oriel 734 monochromator, and the geometry used in reconstruction was the same as the one used in fabrication. This allowed us to measure the diffraction efficiency, the reconstruction wavelength for maximum efficiency and the spectral response of these gratings.

Table 2. Processing schedule for silver halide sensitized gėlatin holograms (Agfa-Gevaert 8E75 HD plates)

Step	
1. Develop with PAAP developer for 4 minutes at 20°C, pH = 7.8	
2. Rinse in running water for 1 minute	
3. Bleach in a modified R–10 solution for 30 s after the plate has cleared at 50°C (see the formula below)	
4. Rinse in running water for 30 s	
5. Soak in fixer F–24 for 2 minutes	
6. Wash in running water for 10 minutes	
7. Dehydrate in 50% isopropanol for 3 minutes	
8. Dehydrate in 90% isopropanol for 3 minutes	
9. Dehydrate in 100% isopropanol for 3 minutes	
10. Dry in vacuum chamber	
Bleach formula	
Solution A	
Distilled water	500 ml
Ammonium dichromate	20 g
Sulphuric acid	14 ml
Distilled water to make	1000 ml
Solution B	
Patassium bromide	92 g
Distilled water to make	1000 ml
Just before use, mix one part of A with ten parts of distilled water, then add thirty parts of B.	

The processing that was employed is described in Tab. 2 with only slight variations in the concentrations of potassium bromide and potassium dichromate in the bleach. In Figure 1, we show the maximum diffraction efficiency and the wavelength when

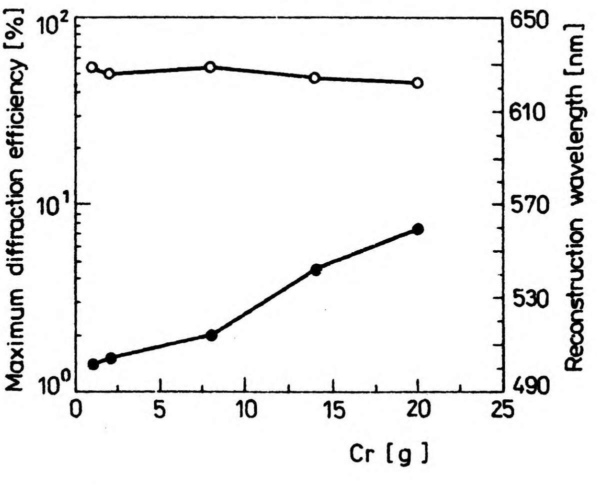

Fig 1. Maximum diffraction efficiency and reconstruction wavelength vs concentration of dichromate, when concentration of bromide 35 g/l remains constant (o efficiency, ● wavelength)

the concentration of dichromate is changed and the concentration of bromide remains constant.

In Figure 2, we show the maximum diffraction efficiency and wavelength when the concentration of bromide is changed, while the dichromate level stays the same. We can see that a change in dichromate for a high concentration of bromide does not affect the maximum diffraction efficiency. However, a change in bromide in

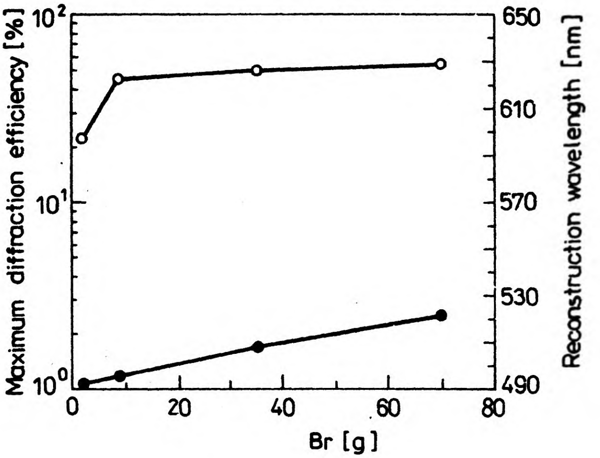

Fig 2. Maximum diffraction efficiency and reconstruction wavelength vs concentration bromide, when concentration of dichromate 2 g/l remains constant (o efficiency, ● wavelength)

relation to the dichromate does indeed have an effect. This is because the bromide controls the average life span of the dichromated ions, producing only a local effect, and as a result, high index modulations can be achieved.

As can be seen, the dichromate is the cause of the variations in the differential hardening. This allows us to vary the reconstruction wavelength by more than 50 nm by appropriately selecting the concentration level of dichromate. Bromide, as we see, also causes small variations in thickness; however, this variation is less than what was cited previously.

Through experimentation it has been shown that it is possible to obtain variations between 50 and 70 nm, in the reconstruction wavelength by controlling the concentration of bromide and dichromate in the bleaching bath.

Nevertheless, it has not been possible to obtain a diffraction efficiency of more than 55% in these tests. Bandwidths of 25 nm were obtained as can be seen in Fig. 3. The energy necessary to do so was 400 μJ/cm^2, much higher than that of a dichromated gelatin.

In conclusion, we can say that it is possible to obtain holographic filters which have a diffraction efficiency of 55% with a bandwidth less than 25 nm, and an energy sensitivity 100 times higher than with dichromated gelatin, by maintaining the

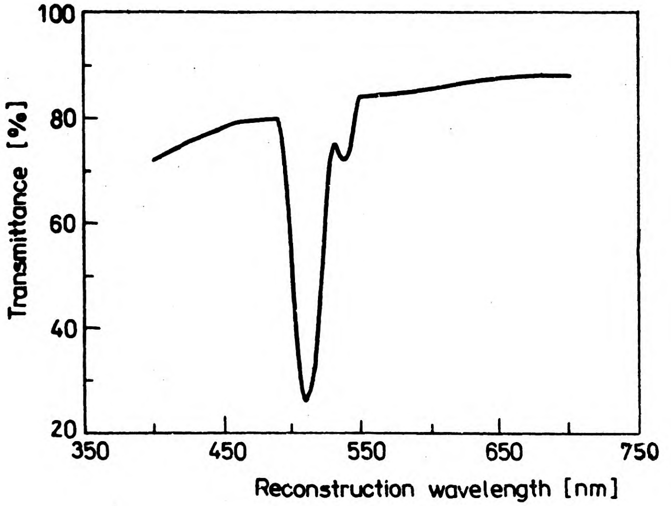

Fig. 3. Transmittance of reflective diffraction grating vs reconstruction wavelength

reconstruction wavelength between 490–560 nm and by adjusting the bleach if a wavelength of 633 nm is used during fabrication.

For experimental purposes, a 10 × 12 cm interferential filter was made using the geometry described in Fig. 4. This filter has maximum efficiency at 555 nm with a 25 nm bandwidth. The emulsion used was Agfa–Gevaert 8E75 HD.

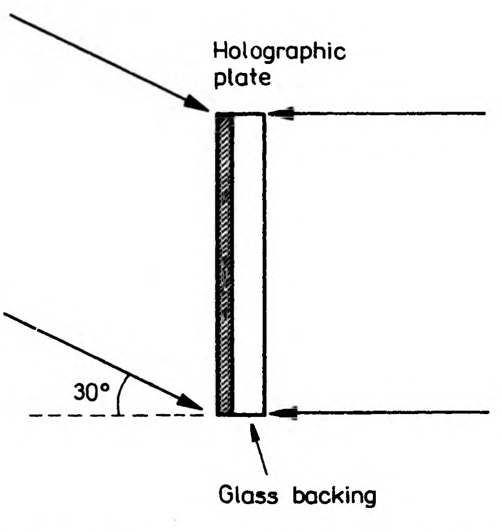

Fig. 4. Geometry used for obtaining reflective holographic optical element as a filter

3. Conclusions

We have shown that it is possible to make reflective holographic optical elements in silver halide sensitized gelatin with diffraction efficiencies higher than 50% by letting the reconstruction wavelength to differ by between 50 and 70 nm, from the recording wavelength.

We have observed the influence that the swelling factor has on the optimization of the processing of SHSG, and pointed out a new relationship between the different latent image formation processes and SHSG.

Finally, the holographic filters made using this technique allow us to combine them with conventional elements in order to incorporate the holographic optics into conventional optics.

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Received July 16, 1991

Отражающие голографические элементы в желатине, сенсибилизованной гологенидом серебра

Было показано, что желатина, сенсибилизованная гологенидом серебра, составляет альтернативу для двухромовой желатины в производстве передающих голографических оптическихэлементов (HOE). В работе обсуждены возможные применения этого процесса в производстве отражающих голографических оптических элементов.

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