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REFLECTION HOLOGRAPHIC OPTICAL ELEMENTS IN SILVER HALIDE SENSITIZED GELATIN

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ABSTRACT

Silver halide sensitized gelatin has proven 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 as well as the possible use of one of them in the construction of a hybrid refraction-diffraction system which could be used to copy transmission HOEs using partially coherent light.

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 is difficult to obtain high diffractin 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. In part 3 we discuss its possibilities as an optical element in a device that is capable of copying transmission HOE with partially coherent light.

2.- THE OPTIMIZATION OF SHSG PROCESSING

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 parts: the 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 measurement 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 that 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 8E75 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 I we show a preprocessing which allows us to modify this swelling parameter. One the plate is preprocessed using this method, we obtain a swelling factor of 200 which also allows us to achive 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 bromide's effect on the average life span of the chromium ions is fundamental because not only does it control its behavior 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 modulations.

The developer used, PAAP, is commonly cited in the literature and allows us to obtain low noise levels[3].

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The rest of the processing is similar to dichromated gelatin processing and is described completely in Table II. 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.

Table I: Preprocessing

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) more than 24 hours

Reflective diffraction gratings were made using off-axis geometry with 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.

The processing that was used is shown in Table II with only slight variations in the concentrations of potassium bromide and potassium dichromate in the bleach. In figure 1 we have shown the maximum diffraction efficiency and the wavelength when the concentration of dichromate is changed and the concentration of bromide remains constant.

Table II: Processing schedule for silver halide sensitized gelatin (SHSG) holograms (Agfa 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 (for formula see 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	
Potassium bromide	92 g
Distilled water to make	1000 ml

Just before use, mix one part A with ten parts distilled water, then add thirty parts B

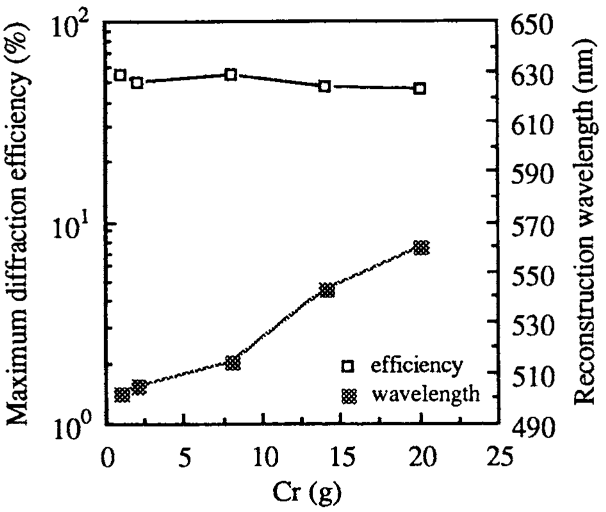

Figure 1

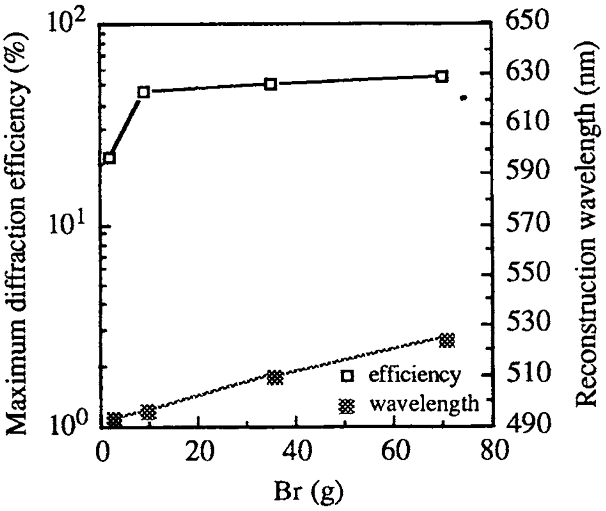

Figure 2

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 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 differencial 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 figure 3. The energy necessary to do so was 400 μJ/cm^2, much higher than that of a dichromated gelatin.

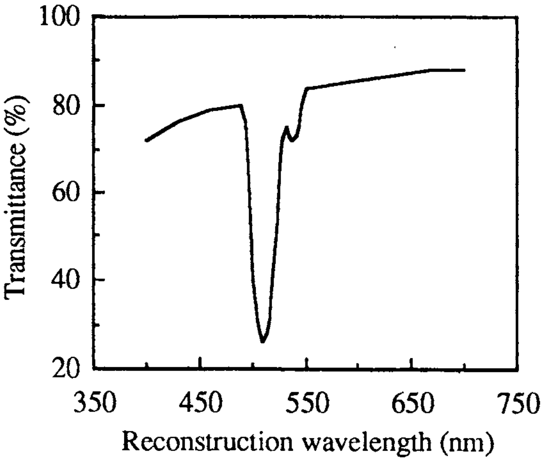

Figure 3

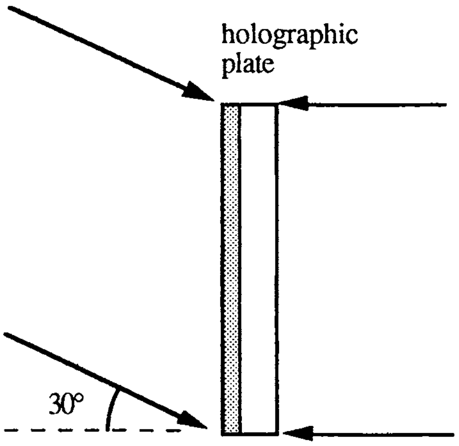

Figure 4

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 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 x 12 cm interferential filter was made using the geometry described in figure 4. This filter have maximum efficiency at 555 nm with a 25 nm bandwidth. The emulsion used was Agfa-Gevaert 8E75 HD.

3.- COPYING TRANSMISISION HOE

The incorporation of holographic optics into conventional optics has allowed the development of new devices and geometries in the design of new optical systems. A great number of holographic systems have been produced. In figure 5 we show a hybrid optic system which lies between the conventional and the holographic and which permits us to copy transmission HOE with partially coherent light.

Conventional optics has contribute by providing the reconstruction beam for the HOE and this beam serves as an interferential filter. The results is that from one finite source size of white light it is possible to obtain a collimated beam which has a bandwidth of 25 nm and a usable diameter, in our case, which measures 10 cm.

The experimental conditions in terms of the size of the source used and the width os the interferential filter allowed us to obtain coherence conditions that surpassed 0.9, sufficient for making copies.

The copying process is based on storing the diffracted wavefront and the zero order wavefront in a second material and bringing the original and the copy into contact, thereby registering the interferential figure in the copy. The coherence conditions allow us to have enough contrast in the fringes to obtain diffraction efficiencies in the copy that are similar to those obtained when using conventional methods.

In order to demonstrate the method's posibilities, transmission gratings were copied using a master made in SHSG and using a photographic emulsion as the material for the copy. In Table III we have show the processing that we used, and the diffraction efficiency results (measured with 633 nm wavelength) are shown in figure 6. As we can see, the efficiencies obtained are 40% close to the 60% that are obtained in this process when using conventionals methods.

Table III: Processing schedule for bleached emulsion (Agfa 8E75 HD plates)

STEP

1.- Develop with AAC developer for 4 minutes at 20° C
2.- Rinse in running water for 1 minute
3.- Bleach in R-10 solution for 30 s after the plate has cleared at 50° C
4.- Wash in running water for 10 minutes
5.- Dry at 20° C

BATHING COMPOUNDS

AAC Developer

1-ascorbic acid	18 g
Sodium carbonate	60 g
Distilled water to make	1000 ml

R-10 bleach

Potassium dichromate	2 g
Sulphuric acid	10 ml
Potassium bromide	35 g
Distilled water to make	1000 ml

We have already reported the possibility of extending the method to other recording materials and with other geometries in previous papers[4].

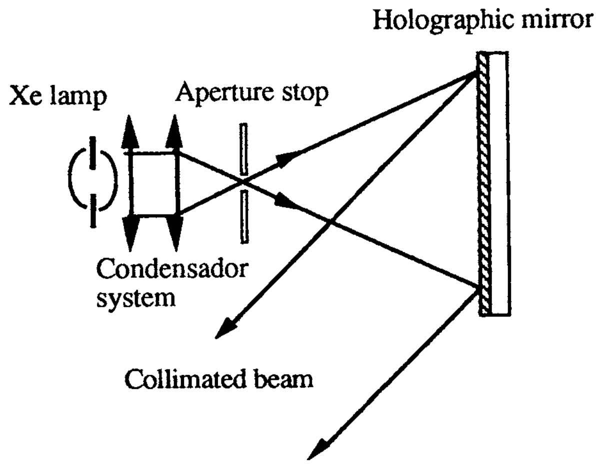

Figure 5

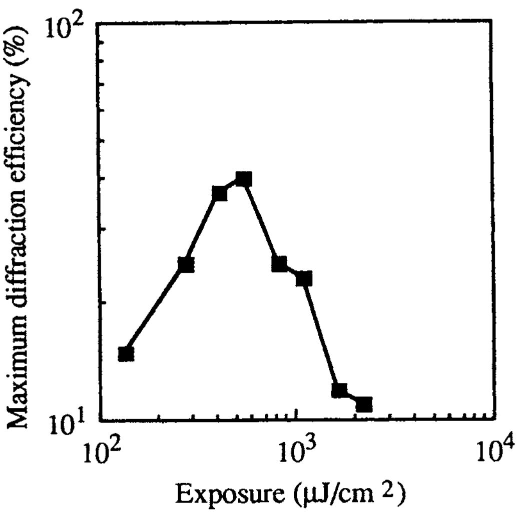

Figure 6

4.- 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 keeping the reconstruction wavelength between 50 and 70 nm, from the recording wavelength.

At the same time we have shown that the holographic filters made with this technique allow us to combine them with conventional elements in order to design optical systems for use in copying transmission HOEs with results that are comparable to those obtained and reported in the literature for the process used.

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

5.- REFERENCES

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