Noise gratings recorded with single-beam exposures in silver halide emulsions: The influence of the bleach bath

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ABSTRACT

Noise gratings recorded with single-beam exposures in bleached silver halide emulsions are analyzed as a function of chemical processing. Two types of bleach baths were used in these experiments (one reversal and the other rehalogenating) and the characteristics of these gratings were determined by measuring the transmittance through the processed hologram as a function of the replay angle. The results obtained show that the study of these noise gratings provides information about the bleaching action during the processing.

1.- INTRODUCTION

Noise gratings are spurious grating structures recorded at the same time as the desired hologram due to scatter from inhomogeneities in the photosensitive material [1]. The noise gratings reduce diffraction efficiency and signal-to-noise ratio during hologram reconstruction and significantly hamper efforts to obtain high-quality holograms. Due to the fact that silver halide emulsion consists of fine grain silver halide crystals suspended in a gelatin base, the effect of noise gratings on holograms recorded in photographic emulsions is significant [2-4]. During hologram formation the scattered field from the photosensitive silver halide grains interferes with the incident beams and gives rise to noise gratings after processing. The efficiency of these noise gratings depends to a great extent on the processing chemistry [5] (basically, if the process introduces very small emulsion thickness changes, the diffraction efficiency of noise gratings is quite pronounced), the relative polarization between the recording and reconstruction beams [6] and the reconstruction wavelength [4, 7].

It is possible to record noise gratings with a single-beam of coherent light [4-8]. In this situation, the incident beam interferes

with its own scattered radiation field to record the hologram. Syms *et al.* [2] have pointed out that one method of analyzing these gratings is to measure the transmittance of the plate after processing as a function of the reconstruction angle. The scattered field from noise grating causes a drop in the transmitted intensity when the single-beam hologram is reconstructed under similar conditions to those used for recording. Kostuk *et al.* [6] have shown that noise gratings are sensitive to the relative polarization between the construction and reconstruction beams. When polarized reconstruction and recording beams are orthogonal, the transmitted intensity is greater when the polarization of the beams are identical. As a result, this is an effective method to characterize the noise gratings.

The purpose of the present paper is to describe and discuss the characteristics of noise gratings recorded with single-beam exposures in bleached silver halide emulsion. We propose to shown that the study of these gratings enables us to obtain information about the mechanism of the chemical process and, in particular, the influence of the bleach bath on diffraction efficiency of noise gratings. Phillips [9] has analyzed the properties of silver halide emulsions suitable for holographic recording and the methods of

processing subsequent to exposure, and Hariharan *et al.* [10-12] have analyzed the influence of developer and bleach bath composition studying diffraction efficiency and scattering in holographic gratings. We now consider variations in the transmittance of noise gratings as a function of exposure and bleach bath composition. Analyzing these transmittance variations we can identify the effects of bleaching on holographic recording material and on holograms recorded in this medium.

2.- EXPERIMENTAL

Noise gratings were recorded by a single collimated beam polarized perpendicular to the plane of incidence, from a 15 mW He-Ne laser at a wavelength of 632.8 nm in Agfa Gevaert 8E75 HD emulsion. Single-beam exposures were made with the illuminating beam entering normal to the surface of the photographic emulsion (Figure 1 (a)) and with exposures varying between 17 $\mu\text{J}/\text{cm}^2$ and 534 $\mu\text{J}/\text{cm}^2$. Spurious reflections were eliminated by placing an index matched absorbing layer against the glass side of the photographic plate.

The exposed plates were developed in AAC developer made up of ascorbic acid and sodium carbonate [13]. We eliminated the hydroquinone, metol and phenidona components in the developer to avoid the influence of the oxidized products of the developer on scattering [10]. The developed plates were rinsed briefly and bleached without a fixation step [14]. Two types of bleach baths were used in these experiments. One was modified R-9, a reversal bleach, which consists of a diluted acidified solution of potassium dichromate. The other type was modified R-10, which is a dichromated rehalogenating bleach bath which consists of a diluted acidified solution of potassium dichromate with a small amount of potassium bromide added to it. The difference in the composition of these two bleach baths is the potassium bromide. The processing procedure for the rehalogenating and for the reversal bleach and the developer and bleach formulas are given in Tables I and II.

3.- RESULTS AND DISCUSSION

To evaluate the influence of the bleach bath on noise gratings recorded with a single-beam, we measure the intensity of

the transmitted beam through the plates as a function of the replay angle (Figure 1 (b)), using the same wavelength that was used during the recording stage (632.8 nm). Figure 2 shows an example of these measurements which correspond to a rehalogenating bleach and an exposure of $136 \mu\text{J}/\text{cm}^2$. In this figure, the solid curve represents transmittance with a perpendicular polarized reconstruction beam and the dashed curve the transmittance of a parallel polarized reconstruction beam. In the last case we obtained a considerably smaller dip in transmission (the transmitted intensity is $\sim 50\%$ greater) [6].

Plots of the transmittance as a function of the reconstruction angle for different exposures are shown in Figures 3 (a) and 3 (b). In these figures the solid and the dashed curves are transmittances with the rehalogenating bleach (R-10) and the reversal bleach (R-9), respectively.

Figure 4 shows transmittances for R-10 and R-9 bleach baths, as a function of exposure when the reconstruction and recording angles coincide (i.e., 0°).

As we can see from Figures 3 and 4, the effects of the reconstruction angle, exposure and type of bleach bath is important on the diffraction efficiency of noise gratings. First of all we see that

transmittance is lower when using a rehalogenating bleach than when using a reversal bleach, and this difference is even more accentuated when the reconstruction angle is 0° . Since the same developer is used, the difference that are produced prove that the variations in transmittance are due solely to the bleaching step.

Rehalogenating bleaches produce a phase hologram by transferring silver halide from exposed areas to adjacent unexposed areas [12]. As we can see in Figure 3, when rehalogenating bleach is used, the effects of noise gratings are quite significant. For exposures between $102 \mu\text{J}/\text{cm}^2$ and $136 \mu\text{J}/\text{cm}^2$, transmittance is practically null for a reconstruction angle of 0° , which implies that almost all of the incident light is diffracted by the noise gratings recorded on the recording material. Figure 4 shows that transmittance decreases in relation to exposure, and that for high densities, it increases slightly. This increase of transmittance at high levels of exposure is due to the depletion of the reservoir of unexposed silver halide grains [10]. Another important aspects that can be observed when using R-10 is that the angular bandwidth of the transmittance curves also varies in relation to exposure. As exposure time is increased, bandwidth also increases reaching a maximum value when exposure is $272 \mu\text{J}/\text{cm}^2$. However, the high densities this bandwidth curve begins to

decrease again. Moreover, the resulting emulsion thickness change introduced with this procedure [6,15] is very small ($<0.05\mu\text{m}$). When the process does not change the thickness, the noise grating efficiency recorded during the construction stage does not vary due to the processing. Then, when reconstruction and recording angles coincide, it is possible to satisfy Bragg's Law simultaneously for every elementary grating of the noise grating. In this case, the results obtained for the R-10 bleach imply that the thickness does indeed vary, because the value for transmittance for a reconstruction angle of 0° is small.

The reversal bleaches produce a dissolution and removal of the developed silver leaving a phase hologram made up of the unexposed silver halide grains. In Figure 4 we can see that the minimum transmittance value for reversal bleaches is greater than that for rehalogenating bleaches and that the curve is slightly truncated with no clear peak for a reconstruction angle of 0° . The decrease in transmittance due to the presence of noise gratings is quite small in this case, with the minimum obtained being 65% (Exposure = $102 \mu\text{J}/\text{cm}^2$). If these noise gratings did not exist, transmittance would be in the area of 80% (see graphs in Figure 3). Transmittance also depends upon exposure as is the case with

rehalogenating bleaches. For short exposures the effect of the noise gratings is also minimal and as exposure increases, transmittance decreases, but for very large exposures, the efficiency of these noise gratings decreases (see Figure 4). As a matter of fact, the decrease in transmittance due to noise gratings for exposures that are greater than $272 \mu\text{J}/\text{cm}^2$ is less than 5%. Nevertheless, this variation due to exposure is less significant than the variation due to the use of a rehalogenating bleach. This behavior of transmittance variations is related to the type of bleaching agent used. R-9 bleaches act brusquely due to their solvent action and this produces considerable thickness variations [15] with the highest values produces for high exposure rates. Due to this variation in thickness, the complex structure of noise gratings change and produces a subsequent change in the orientation of the various grating vectors. In this type of situation, it is impossible to satisfy Bragg's Law for all gratings simultaneously; the decrease in diffraction efficiency is dramatic and as a result, plate transmittance goes up. This also explains why the peak of the transmittance curve is truncated or why there are two small peaks near the 0° reconstruction angle. In the first case it means that Bragg's Law is satisfied for both angles in the majority of noise gratings, and in the second, that for 0° , the slight increase in

transmittance implies that the number of gratings that satisfy Bragg's Law is low. Thus, the results of measuring transmittance as a function of the reconstruction angle of the noise gratings when using R-9 bleach show that there is a considerable variation in thickness.

Finally, we would comment that the difference between the maximum transmittance values obtained with R-10 (~70%) and R-9 (~80%) bleaches also provides information about the behaviour of these processes. The fact that transmittance is lower in the first case shows that more light is diffused and absorbed than in the second case. This is due to the fact that the size of the grain after rehalogenating bleach bath is greater than after reversal bleach bath [15], which produces greater scattering when using a rehalogenating bleach. The presence of potassium bromide in bleach bath produces an increase in scattering [12, 14].

4.- CONCLUSIONS

Our experimental results (shown in Figures 3 and 4) clearly confirm the effects of chemical processing on recorded noise

gratings in silver halide emulsions. In particular we can see that different behaviors are produced when the bleaching agent is changed. In our experiments, the two bleaching solutions that have been used differed "only" in that the rehalogenating bleach contained 35 g of potassium bromide per liter of water. An important result is that the thickness variations in volume holograms formed in bleached photographic emulsion reduce the negative effects of noise gratings.

It is possible to analyze and optimize the photochemical bleaching processes that are produced during chemical processing by analyzing transmittance as a function of the reconstruction angle of the noise gratings recorded with a single beam of light. The results we obtained with the two types of bleaching solutions (such as thickness variations for example) are similar to those obtained using other methods [14,15]. On the other hand, the analysis of the noise gratings recorded with a single beam of light is an effective method for studying the mechanism of the bleaching action. And finally, these experiments do support the important conclusion that it is possible to find bleaches that reduce the negative effect of noise gratings and identify the exposure values at which the effect of the noise gratings is minimized.

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FIGURE CAPTIONS

Figure 1: Arrangement for (a) recording and (b) reconstruction the noise gratings.

Figure 2: Transmittance *vs* reconstruction angle for noise gratings recorded with construction beam polarized perpendicular to the plane of incidence. The solid and the dashed lines are transmittances with a perpendicular polarized reconstruction beam and with a parallel polarized reconstruction beam, respectively.

Figure 3: Transmittance as a function of the reconstruction angle for exposures (a) 17, 34, 51 and 68 $\mu\text{J}/\text{cm}^2$; (b) 102, 136, 272 and 534 $\mu\text{J}/\text{cm}^2$. The solid and the dashed curves are transmittances with the rehalogenating bleach (R-10) and the reversal bleach (R-9), respectively.

Figure 4: Transmittance *vs* exposure for R-10 and R-9 bleach baths when the reconstruction and recording angles coincide (0°).

TABLES

Table I: Processing schedule.

Table II: Developer and bleach bath formulas.

TABLE I

PROCESSING SCHEDULE

STEP

- 1.- Develop (see Table II) for 4 minutes at 20° C
 - 2.- Rinse in running water for 1 minute at 20° C
 - 3.- Bleach (see Table I) for 1 minute after the plate
has cleared at 50° C.
 - 4.- Wash in running water for 5 minutes at 20° C
 - 5.- Dry (20° C and 60% RH)
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TABLE II

DEVELOPER AND BLEACH FORMULAS

AAC DEVELOPER

1-Ascorbic acid	18 g
Sodium carbonate	60 g
Distilled water to make	1 liter

REHALOGENATING R-10 BLEACH BATH

Potassium dichromate	2 g
Sulfuric acid, conc.	10 ml
Potassium bromide	35 g
Distilled water to make	1 liter

REVERSAL R-9 BLEACH BATH

Potassium dichromate	2 g
Sulfuric acid, conc.	10 ml
Distilled water to make	1 liter

Fig. 1

Figure 1
A. Belén
Noise gratings

Fig. 2

Fig. 3

Fig. 4