COPYING LOW SPATIAL FREQUENCY HOLOGRAMS IN SILVER HALIDE EMULSIONS: THE INFLUENCE OF THE BLEACH BATH

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We present an available and low cost technique for the production of binary-phase diffractive optical elements designed by digital methods. We produce binary-amplitude holograms making use of a high resolution graphic device. They are used as binary masks which are copied on silver halide photographic emulsion. The behaviour for low spatial frequencies of three different bleaching processes has been studied. Finally, we have applied the technique for the production of filters for optical correlation. As a conclusion, we find that solvent and conventional bleaches are more suitable for low spatial frequency holograms than the fixation-free rehalogenating bleach.
Keywords: computer-generated-holograms, laser printer, recording materials, hologram-copying

Introduction.

In previous papers it has been suggested that it is possible to mass produce holographic optical elements [1,2] and computer-generated-holographic interconnects [3] through a copying process by the use of partially coherent light. In this paper we show that it is possible to obtain spatial filters and Fresnel lenses for optical information processing by using a copying hologram method. Low spatial frequency diffraction gratings are copied using this method in bleached silver halide emulsion. A big effort in literature has been focused on the optimization of bleaching procedures for high spatial frequencies as can be seen in [4], but low frequencies have been scarcely studied. In this paper we will show some results of the performance of the bleaches for low spatial frequencies.

The copying process used in this work consists of storing the interference pattern generated in the master in a holographic recording material. The master is placed in direct contact with the recording material, with the master and the photosensitive layer of the copy placed together [1]. Working with partially coherent light enables to work with more economical sources and devices, and provides stabiliy conditions that are not as strict as those used in conventional holographic devices.

The master used in the copying process has been designed by computer techniques [5]. We save the design in a PostScript file, which is printed by a Linotronic printer on photographic film. The Linotronic printer is a high resolution (3251 dots/in) commercial laser writer usually used in graphic arts. This printer permits the modulation of the transmittance of the photographic film. The dimensions of the master are 3 cm x 3 cm, and it contains different gratings of dimensions 8 mm x 8 mm. They are amplitude gratings with binary transmittance, the spatial frequency of which ranges from 4 lines/mm to 32 lines/mm, which is the maximum reachable by the Linotronic printer we have used. Therefore, we are dealing with an inexpensive and available technique for the generation of low spatial frequency diffractive optical elements.

Low spatial frequencies study.

The master is copied onto 8E56 HD Agfa-Gevaert photographic emulsion. In the course of our experiments a collimated beam from a high-pressure mercury lamp, filtered at 405 nm and incident to the master and copy, is used to expose the photographic emulsion. The exposures vary between 10 and

425 μJ/cm^2 and the exposed plates are developed in AAC developer [6] made up of ascorbic acid and sodium carbonate. Three types of bleaching techniques are used [7]: conventional (rehalogenating) bleaching, fixation-free rehalogenating bleaching and reversal (or solvent) bleaching. With these processes phase elements are obtained.

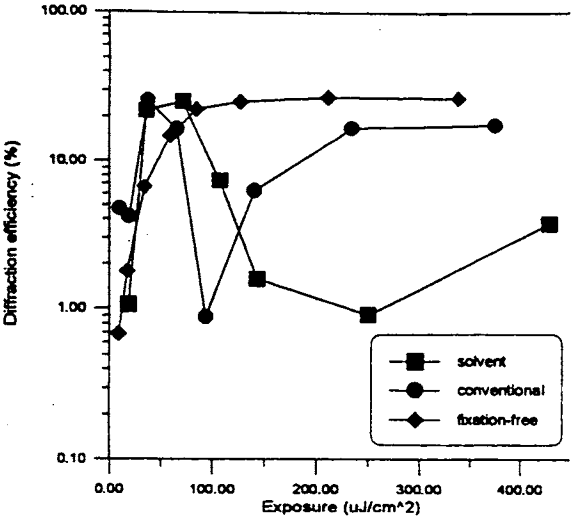

Figure 1. Diffraction efficiency vs. exposure for the grating of 18 l/mm and the three bleaching processes

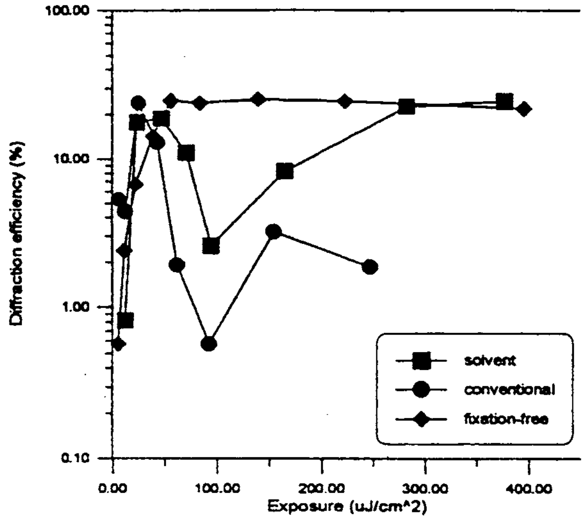

Figure 2. Diffraction efficiency vs. exposure for the grating of 32 l/mm and the three bleaching processes

After processing, the copies are illuminated with a plane wave coming from a He-Ne laser (λ = 632.8 nm) entering normal to the surface of the photographic emulsion. The diffracted beam intensity is measured and the diffraction efficiency is calculated as the ratio between the power in the first diffracted order and the incident power. Maximum diffraction efficiencies achieved are over 25 % in the three bleaching procedures, as can be seen in figure 1 and in figure 2. Taking into account loses due to reflection and absorption the maximum diffraction efficiency that can be achieved by a binary phase simmetrical grating is around 30 %. The fact that the resulting gratings are not perfectly binary can explain the 5 % of difference between experimental and theoretical diffraction efficiency.

Figures 1 and 2 show the influence of the bleach bath on the diffraction efficiency of the copies for gratings of spatial frequencies of 18 l/mm and 32 l/mm respectively. What we find as the most noticeable feature in these figures is the different behaviour of fixation-free rehalogenating bleach in comparison with the other two bleaches. In fixation-free bleach, diffraction efficiency monotonically increases with exposure tending to a saturation plateau, while solvent and conventional bleaches have more than one local maximum.

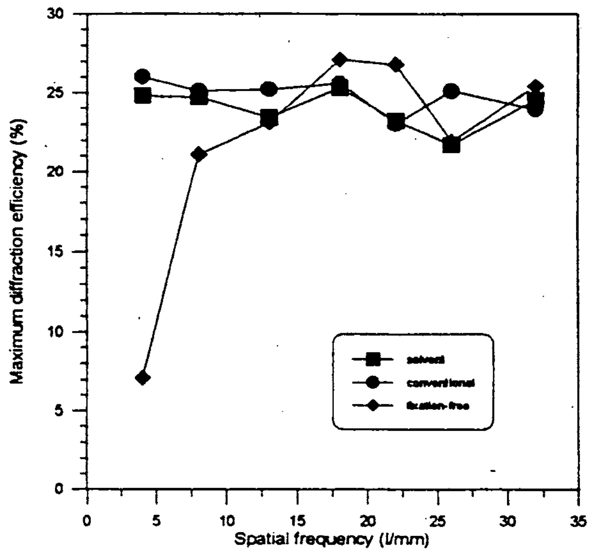

Figure 3. Spatial frequency response of the three bleaches

In figure 3 we compare the behaviour of the three bleaches in terms of the maximum diffraction efficiency obtained for each of the gratings we have copied. We find that fixation-free rehalogenating bleach response is frequency dependent. Therefore, solvent and conventional bleaches, which have a flat frequency response, are more suitable for the fabrication of diffractive optical elements. The reason is that holograms are composed of a combination of multiple spatial frequencies. It is important to notice that fixation-free rehalogenating bleach is the best considered bleach at high frequencies [7], but from our study we can conclude that at low frequencies solvent and conventional bleaches provide a better performance.

Application to phase filters fabrication.

Once we have optimized the technique we have obtained Fresnel lenses with different focal lengths and filters for pattern recognition. As an example of results we will show experimental values from a pattern recognition problem. We have encoded a phase-only filter (POF) [8] by using the Burckhardt's method [9]. We have compared the experimental correlations obtained with three filters copied from the same POF and bleached with the three studied methods. In table 1 we show the results. We must note that the discrimination capability is defined as:

$$DC = 1 - \frac{\textit{maximum crosscorrelation peak}}{\textit{maximum autocorrelation peak}} \quad (1)$$

We find that solvent and conventional bleaches provide the highest autocorrelation peaks, being three times more energetic than the autocorrelation peak produced by the amplitude hologram generated by the Linotronic. The discrimination capability is ensured with any of the three bleaches.

FILTER	AUTOCORRELATION PEAK (ARBITRARY UNITS)	DC
Master	66	0.70
Solvent	196	0.63
Conventional	200	0.65
Fixation-free	172	0.65

Table 1. Performance of the filters for optical correlation

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