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Thick phase holographic gratings recorded on Agfa 8E75 HD, BB-640 and PFG-01 red sensitive silver halide materials

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ABSTRACT

Two particular techniques producing high quality thick phase holograms in silver halide emulsions are the fixation free rehalogenating bleaching and the silver halide sensitized gelatin. In this work we compare these two particular techniques applied to three different red sensitive emulsions: Agfa 8E75 HD, BB-640 and PFG-01. The differences between the emulsions influence in the particular experimental conditions which yield to holograms performing high diffraction efficiencies. In this work these differences are analyzed and also its influence on the final hologram.

1. INTRODUCTION

Holographic optical elements (HOE's) are one of the most important applications of Holography[1]. A great deal of research has been carried out over the last decades in order to find the optimum materials for recording of HOE's. There is a great variety of materials showing good performance such as dichromated gelatins, photopolymers and photorefractive materials. Among these materials photographic emulsions are still one of the most widely used[2]. They present high energetic and spectral sensitivity, and are widely available on the market. Furthermore, they show repeatability of results and ease of processing.

Although photographic emulsions can be prepared in a holography laboratory, the preparation of these materials is a tedious and difficult process. Therefore it is advisable to use commercial emulsions. The use of commercial materials is also advantageous because the procedures that are optimized in one Lab for these emulsions can be used in another if only slight modifications are made. The first series of photographic emulsions for laser recording were introduced in the Western market by the Kodak company. Then, the Agfa company created a line of production dedicated to the manufacture of photographic emulsions for holography. However, Agfa stopped production of materials for holographic applications in 1997. Nowadays there are two main companies which produce silver halide materials for holography on a large scale; these are the Slavich company from Rusia, and Colourholographics from UK, with the BB series. A lot is known about Agfa products because these silver halide materials dominated the market in the 80's and 90's, so much research has been done on them. Nevertheless, the same is not the case for the materials from the Slavich and BB companies, at least when western procedures are to be used with these materials.

2. RESULTS AND DISCUSSION

There are two main differences between BB-640, Agfa 8E75 HD and PFG-01 emulsions: the grain size of the silver halide grains suspended in the gelatin of the emulsion and the degree of hardening of the gelatin of the plates. The first influences the scattered light intensity during the recording and also during the reconstruction of the final holograms, whereas the second influences the temperature of the baths included in the different procedures. By taken into account these differences between the emulsions two procedures were optimized: The silver halide sensitized gelatin[3,4] and the fixation-free rehalogenating bleach[5,6].

In order to optimize the procedures described, unslanted phase transmission gratings with spatial frequency of 1200 lines/mm were recorded by the interference of two collimated beams from a He-Ne laser (633 nm). After that the plates underwent two different chemical procedures: a silver halide sensitized gelatin procedure and a fixation-free rehalogenating bleaching procedure. In order to get information about the particular mechanisms which create the refractive index modulations in the two procedures studied we made use of Kogelnik's Coupled Wave Theory[7]. The

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theoretical transmittance was fitted to the experimental data of the angular response of the transmittance for the different diffraction gratings recorded in this work. By doing this we obtained information about the refractive index modulation and the thickness of the holograms. In the case of the holographic diffraction gratings recorded in this work, the product of the refractive index modulation with the thickness, Δnd, needed to obtain a theoretical diffraction efficiency of 100% must be ~0.308 μm[8]. Table I shows the values obtained after the theoretical fitting of the transmittance as a function of the angle for silver halide sensitized gelatin transmission holograms which yielded to the maximum diffraction efficiency recorded on three different emulsions: Agfa 8E75 HD, BB-640 and PFG-01 plates. Whereas Figure 1 shows the values of the product Δnd as a function of the exposure for fixation-free rehalogenating holograms recorded on the three emulsions considered bleached with the optimum B/A ratio in each case. As can be seen, in the case of fixation free rehalogenating holograms the value of Δnd which yields to a maximum diffraction efficiency of 100% was reached and even surpassed in the case of BB-640 and Agfa 8E75 HD emulsions. This didn't occur in the case of PFG-01 plates, but the product Δnd was kept near ~0.31 μm, over 0.26 μm (with a theoretical diffraction efficiency of 94%), in the range of exposures from 700 to 2400 μJ/cm^2. On the other hand with respect to silver halide sensitized gelatin holograms, the values of the maximum diffraction efficiency that could be reached if the holograms didn't present absorption and scatter losses would be of ~99% for Agfa 8E75 HD and Slavich PFG-01 emulsions and 94% for BB-640
emulsions.

Table 1. Parameters obtained after the theoretical fit of the angular response of the transmittance for silver halide sensitized gelatin recorded on three different emulsions.

	BB-640	Agfa 8E75 HD	PFG-01
d (μm)	10.7	6.0	7.8
αd	0.062	0.200	0.078
Δn	0.0243	0.0479	0.0373

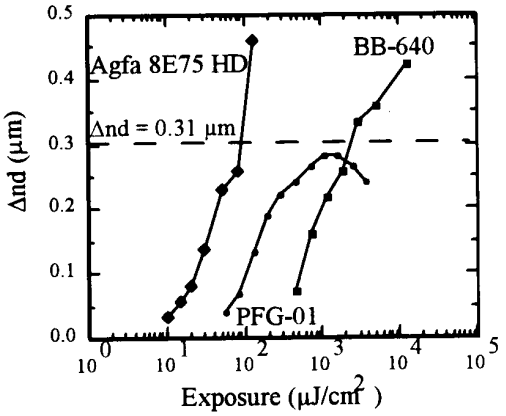

Figure 1. Product Δnd as a function of the exposure for fixation-free rehalogenating bleached holograms.

3. CONCLUSIONS

In order to create volume phase holograms recorded on BB-640, PFG-01 and Agfa 8E75 HD plates it is necessary to take into account the differences presented by the three emulsions. By doing this we have optimized two different procedures: silver halide sensitized gelatin and fixation-free rehalogenating bleaching for the recording of volume phase transmission diffraction gratings. We have demonstrated that a maximum theoretical diffraction efficiency of 100% can be achieved with the two different procedures. The theoretical maximum diffraction efficiency is, then, only limited by absorption and scatter losses.

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