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Silver halide sensitized gelatin as a holographic storage medium

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ABSTRACT

Silver halide sensitized gelatin is one of the most promising techniques for the manufacturing of transmission holographic optical elements. These techniques combine the relatively high sensitivity of photographic material with the low scattering and high light-stability of dichromated gelatin. The influences of the developer and the bleaching in the diffraction efficiency and noise is analyzed starting with Agfa 8E 75 HD plates.

According to P. Hariharan,⁵ we analyzed the processing steps and this show that the developer action influences on the noise level and the modulation transfer function. The developer of the type PAAP produces better resolution and less noise level than the developer D-19.

The bleaching action is related to the diffraction efficiency and the hardening level of the gelatin. The hardening action is promoted by trivalent chromium ions which are generated in the vicinity of the oxidized silver grains and controlled by the ratio concentration to the Cr^{+3} ions and Br^- ions of the bleaching bath. The measurements of the diffraction efficiency in the different steps of the processing give us information about the mechanism of hologram formation.

1. INTRODUCCION

Silver-halide sensitized gelatin is a processing technique which combines the energetic and spectral sensitivity of photographic emulsions with a high diffraction efficiency and the low level of noise of dichromated gelatins.

The technique was initially developed by Penington, Harper and Laming,¹ though the technique in its present day state is due to the works of Graver, Gladden and Estes² on the one hand and to those of Chang and Winick³ on the other.

One of the problems involved in this processing technique lies in the fact that the resolution power is dependent on that of the photographic emulsion. Ferrante⁴ has studied this aspect closely and has found a significant decrease when we get to 2000 l/mm. Hariharan,⁵ in his turn, has analysed the influence of the developing, whereas Angell⁶ has recently optimized the processing for the Kodak 649F emulsion.

In this work we are going to show the results we have obtained for the Agfa 8E75HD emulsion, these being based on a modification in Chang and Winick's processing for this technique and on Chang's^{7, 8} results with dichromated gelatin.

2. PHOTOCHEMICAL PROCESSING

On table 1 are shown in detail all the stages in the processing of 8E75HD plates.

For its development we built up holographic diffraction networks between 1000 and 2000 l/mm, which we obtained in a conventional holographic device of symmetrical geometry, by using a He-Ne laser.

Once the photographic emulsion has been exposed it is developed and then bleached. Due to the action of the bleacher the developed silver is oxidized to Ag^+ , whereas the Cr^{+6} ion is reduced to Cr^{+3} during the same bleaching wash. This way the Cr^{+3} ion is linked to the gelatin chains in the vicinity of the oxidized silver grains achieving a variation of hardening between the exposed and nonexposed zones of the emulsion.

The emulsion is then fixed to remove all the excess silver halides. The processing is completed with the washing of the emulsion and its dehydration through successive baths in isopropanol, following a processing similar to that of a dichromated gelatin.

With this classic processing we achieve a 50% diffraction efficiency for networks with the 8E75HD emulsion, a worse result than the one obtained by Angell. From our point of view, this drop is due to the fact that the degree of hardening that is reached in the 8E75HD emulsion gelatin is not the right one, if we compare it to that of the 649F emulsion.⁹

Table 1. Processing schedule for silver-halide sensitized gelatin holographic plates) (all solutions at 20°C)

Step	
1.	Develop with Kodak developer D-19 for 5 minutes.
2.	Rinse in running water for 1 minute.
3.	Bleach in a modified R-10 solution for 30 seconds after the plate has cleared (for formula see below).
4.	Rinse in running water for 30 seconds.
5.	Soak in fixer F-24 for 2 minutes.
6.	Wash in running water for 10 minutes.
7.	Dehydrate in 50 per cent isopropanol for 3 minutes.
8.	Dehydrate in 90 per cent isopropanol for 3 minutes.
9.	Dehydrate in 100 per cent isopropanol for 3 minutes.
10.	Dry in vacuum chamber.
Bleach formula	
Solution A	
Distilled water	500 ml
Ammonium dichromate	20 g
Concentrated 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.

Taking into account that the linking point between the processing of a photographic emulsion and that of a dichromated gelatin is the wash in water (table 1, step 6), we think it is in this point where we can establish a control for the analysis of the processing and its subsequent optimization.

Thus, from this stage, we have measured the diffraction efficiency, by means of which we have studied the aspects which have an influence on the formation of a latent image during this processing: the developer and the bleaching. We shall study them separately in the following sections, finding the possibility of optimization which we have referred to.

2.1. The influence of the Developer

As is already known,⁵ the developer has, due to its composition, an influence on the final diffraction efficiency as well as on the value of the modulation transfer function.

As can be seen in fig. 1 the results of the measurement on diffraction efficiency in the wash in water for developers of the D-19 type are better than the ones we get for developers of the PAAP type. Nevertheless, final efficiency in the drying is higher in 2000 1/mm for the PAAP than for the D-19. That is due to the fact that the oxidation products coming from the hydroquinone, which favour in low frequencies the obtaining of the final differential hardening, turn out to have a negative action for high resolution values. It is possible then to improve the results obtained for high frequencies by working during the processing with developers which don't give rise to oxidation products.

2.2. The influence of the Bleaching Process

At this stage of the processing we can choose between two possible ways. On the one hand it is possible to modify the degree of hardening of the gelatin and on the other hand, we can operate through the composition of the same bleacher.

We have presented in fig. 2 diffraction efficiencies measured in the water wash and after the final drying. In both cases, we show the results for two different temperatures of the bleacher.

As can be seen, the increase in temperature brings about an increase in diffraction efficiency, which comes as a direct consequence of the higher variation of the average hardening of the gelatin as temperature rises.

Figure 2.

Figure 3.

The use of washes in water before and after the bleaching process at a temperature of 50°C leads to an increase in diffraction efficiency during the final stage. There is no increase in efficiency, however, in the intermediate stage of the wash in water, which prevents us from reaching the highest possible efficiency in these cases, as we can see in fig. 3.

The second₃ effect of the developer depends on the concentrations of bromide and dichromate ions₃ that are used, so that the higher the ratio between Br⁻ ions with respect to Cr⁺⁶ ions, the higher the diffraction efficiency measured in water and, as a consequence, after the final drying.

3.- PROCESSING OPTIMIZATION

According to what we have seen, the PAAP developer, due to the low content in oxidation products, achieves high diffraction efficiencies, as well as excellent values as regards the modulation transfer curve.

On the other hand, and since the latent hardening image is produced during the wash in the bleacher and considering that during this same stage we can control the average degree of hardening of the gelatin, we can infer that we can possibly optimize the different stages of the photochemical processing in such a way as to make possible the obtention of high diffraction efficiencies within a wide range of frequencies.

In the tests that we have carried out we have checked that a stopping after the bleaching keeping the plate during 24 hours at a relative humidity of more than 80%, produces an improvement in the results obtained.

We present in fig. 4 measurements on diffraction efficiency taken both in the water wash and after the drying, for the case of the PAAP developer, going then on to the stage of bleaching in the way we have shown, and to which we have added a stopping between the bleaching and water washes. As can be seen, the result shows that we can work between 1000 and 2000 l/mm with a modulation transfer function with efficiency values of more than 70%.

We think the optimization as a whole can be the result of a sort of reaction such as the "darkness reaction", as happens in the case of dichromated gelatins used for the

sensitizing of gelatin layers.^{7, 8}

4. CONCLUSIONS

We have described the processing technique for silver halide sensitized gelatin as process typical to dichromated gelatin, with an optimization of the degree of hardening of the gelatin and the shaping of the latent image during the previous stages of developing and bleaching and in the course of the 24-hour stopping situated between the bleaching and the wash in water. We have also used the wash in water before the final drying, as an effective point in which to control diffraction efficiency in the networks obtained.

With the method proposed above, we have achieved an optimization of the processing technique for silver halide sensitized gelatin for the 8E75HD emulsion, which enables us to obtain a diffraction efficiency response of more than 70% between frequencies of 1000 and 2000 1/mm.

5. REFERENCES

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Figure 4.