Bleached silver halide volume holograms recorded on Slavich PFG-01 emulsion: The influence of the developer

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ABSTRACT

Bleached holograms are one of the most interesting techniques used to produce phase holograms of high quality on photographic emulsions. Of particular interest is the method of fixation-free rehalogenating bleaching. In this paper we will study the influence of the development step in the bleaching process applied to Slavich PFG-01 emulsion, a red-sensitive fine grained emulsion from the Slavich Company. We will show that the development influences the optimum concentration of potassium bromide in the bleach solution. We will also show that good results can be obtained by using Slavich PFG-01 plates for a wide variety of developers -in the case of the CW-C2 developer a diffraction efficiency of over 70% was reached-.

KEYWORDS: Holography; Holographic recording materials; Volume holograms; Silver halide emulsions.

1.- Introduction

Bleached silver halide emulsions have long been used as a medium for recording volume phase holograms because they offer several attractive advantages [1]. These advantages include a relatively high sensitivity, ease of processing of the results, improved chemical processing, their availability as commercial films and the repeatability of the results. Volume holograms recorded in silver halide emulsions are commonly bleached to obtain phase holograms in order to increase diffraction efficiency. Unfortunately, although the resulting phase holograms have high diffraction efficiency, this is usually accompanied by an increase in the scattering of light from the silver halide grains [2] and a consequent reduction in image quality.

One of the most important points to take into account in order to increase diffraction efficiency and reduce scattering in a particular bleached emulsion is the influence of the chemical processing and its optimization. In this processing, the development and bleaching steps play an important role because their action influences the image quality (diffraction efficiency and noise) of the final hologram.

The influence of the development step and the bleach solution on the final quality of the bleached hologram has been studied by different authors. The studies were carried out mainly with Agfa 8E75 HD plates. Concerning the bleach bath, different authors have proposed various bleach solutions for the production of high quality phase holograms. Upatnieks [3], for example introduced ferricyanide and copper bleaches, whereas Phillips and Porter [4] used ferric nitrate in the bleach bath. These authors also introduced the Para-Benzoquinone (PBQ) bleach [5], achieving high quality holograms. Another interesting bleach solution was the Kodak R-10 bleach, introduced by Altman [6], and later improved by McMahon and Franklin [7]. The fixation-free method was discovered by Hariharan, and

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this method was subsequently improved by Crespo *et al.* [8]. This technique has the advantage over bleaching with fixation that the shrinkage of the emulsion is minimized. Hariharan and Chidley [9] studied the influence of the potassium bromide concentration on the diffraction efficiency and scattering of the final hologram. In their research they show that the concentration of the potassium halide must be adjusted carefully in order to obtain high values of diffraction efficiency and low values of scattering.

Hariharan also studied the influence of the development step on the quality of the hologram [10]. He showed that the concentration of sodium sulfite influences the quality of the final hologram. This is due to the solvent action of the sodium sulfite. They also show that the action of hardener developers has a counteractive effect on the index modulation created by the diffusion process, so that the diffraction efficiency is decreased when hardener developers are used. We will prove that the use of hardener developers does not prevent high refractive index modulations being achieved. In fact, better results are obtained when these developers are used, for example the CW-C2 developer, which is known for creating a hardening action due to its oxidation products.

The bleach used in our experiments was a modified version of the R-10 bleach, which was introduced by McMahon and Franklin in bleaching techniques. We will also demonstrate that the developer influences the optimum potassium bromide concentration in the bleach solution. Therefore, the two steps, development and bleach bath, must be considered and optimized at the same time. In this study the influence of the development and the bleaching steps were studied by recording holographic transmission gratings on Slavich PFG-01 plates. The use of these Russian plates in the experiments is due to the fact that the well-known Agfa plates are no longer available on the market, since Agfa ceased production of holographic material in 1997 [11]. The void created by the withdrawal of Agfa material must be filled by new photographic materials. With this in mind we studied the Slavich PGF-01 plates, which have been used in Eastern European countries for a long time, but almost no studies have been made applying Western European procedures to these plates. The two emulsions are fine-grained red sensitive holographic emulsions for transmission or reflection hologram recording. According to the manufacturer [1] the Agfa 8E75 HD emulsion has a thickness of ~6 μm, a refractive index of 1.63, a spectral sensitivity in the range of 600 to 700 nm and a mean grain size of 44 nm [12]. In the case of the PFG-01 emulsion we measured experimentally the thickness and the refractive index of the emulsion by using an experimental technique based on the film resonance method proposed by Tholl *et al.* [13], obtaining an emulsion thickness of ~7 μm and a refractive index of 1.61. According to the manufacturer the spectral sensitivity range for PFG-01 emulsion is from 600 to 680 nm and the mean grain size of 40 nm.

2.- Experimental procedure

The experiments were carried out on red sensitive Slavich PFG-01 silver halide emulsion. Unslanted holographic transmission gratings were recorded using two collimated beams from a 15 mW He-Ne laser (633 nm), with the polarization vector perpendicular to the plane of incidence. The two beams, of equal intensity, impinged on the emulsion forming an angle of 45° (in air). With the geometry described, the spatial frequency of the gratings was calculated as ~1200 lines/mm.

After exposure, the plates underwent the schedule procedure illustrated in Table I, so that phase transmission holograms were finally obtained. In order to study the influence of the development step four different developers were used after exposure: D-19, CW-C2, AAC and PAAP. Table II shows the composition of the developers. Due to the softness of the gelatin of Slavich PFG-01 plates [14], the temperature of the bleach bath was maintained

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at 20°C for these plates.

The diffraction efficiency η of the recorded phase holograms was calculated as the ratio of the diffracted beam intensity to the incident collimated probe-beam intensity of the He-Ne laser. Both the incident beam intensity and the diffracted beam intensity were measured in air. Therefore it must be taken into account that part of the incident beam reflects at the interface air-emulsion, whereas part of the diffracted beam reflects at the interface glass-air. The reflection losses were calculated by using Fresnel equations for p-polarized light, and in order to evaluate these Fresnel losses, the expression of the diffraction efficiency was corrected by multiplying by an appropriated factor. By doing this, the obtained diffraction efficiency gives a better measure of the quality of the grating [15]. The efficiency of the zero-order or transmission τ was similarly calculated as the ratio of the directly transmitted beam intensity to the incident power and was corrected by the same factor.

3.- Previous considerations

The equation for diffraction efficiency, given by Kogelnik's theory for phase transmission volume gratings is [16]:

$$\eta = \exp(-\alpha d / \cos\theta') \frac{\sin^2(\nu^2 + \xi^2)^{1/2}}{1 + (\xi^2/\nu^2)} \quad (1)$$

where for grating with unslanted fringes ν and ξ are expressed as follows:

$$\xi = \frac{\pi d}{\Lambda \cos\theta'}\left(|\sin\theta'| - \frac{\lambda}{2n\Lambda} \right) \quad (2)$$

and:

$$\nu = \frac{\pi \Delta n d}{\lambda \cos\theta'} \quad (3)$$

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In equation (1) α takes into account the absorption (and also the scattering; we have no means of differentiating between the two at this point), d is the emulsion thickness, n is the mean refractive index, Δn is the index modulation, Λ is the grating period, λ is the wavelength of reconstruction in air, and θ' is the angle of reconstruction in the medium, which is related to the angle of reconstruction in air θ by Snell's law. For unslanted gratings the grating period is given by equation:

$$\Lambda = \frac{\lambda}{2\sin\theta_0} \qquad (4)$$

where $2\theta_0$ is the angle between the two beams in air. For gratings analyzed in this paper, $\theta_0 = 22.5°$ and $\Lambda = 0.827$ μm.

In equation (1) ξ takes into account the deviation from the Bragg condition and ν controls the maximum diffraction efficiency at the Bragg condition. The maximum diffraction efficiency is achieved at the Bragg angle ($\xi = 0$), when ν takes the value $\pi/2$. In the case of the transmission holograms studied in this Work, when $\nu = \pi/2$, at the Bragg angle (in air) (22.5°) the product $\Delta n \cdot d$ takes the value of 0.308 μm, considering that the refractive index of the emulsions studied was n ~1.61, so that the angle inside the emulsion was ~13.8°. The value of the thickness was found to be ~7 μm for Slavich PFG-01. This means that the highest value of diffraction efficiency is achieved with a high value of a refractive index modulation $\Delta n \sim 0.044$. We will show that rehalogenating bleaching techniques without a fixation step are efficient enough to create this refractive index modulation, by using different developers, when Slavich PFG-01 plates are used to record bleached transmission holograms.

4.- Experimental results

4.1.- Analysis of the bleaching step

In order to study the influence of the development step in the bleaching technique procedures, the plates were bleached with a modified version of the R-10 bleach (Table III).

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The bleach bath solution is composed of two different solutions: A and B. The oxidizer (potassium dichromate) is contained in the solution A, whereas the rehalogenating agent (potassium bromide) is contained in the solution B. To obtained the bleach solution 1 part of A is mixed with 10 parts of distilled water and X parts of B. The ratio X = B/A indicates the relation between the potassium bromide concentration and the oxidizer concentration (potassium dichromate). The concentration of potassium bromide in the bleach bath determines the rate of the diffusion process. A high rate of the diffusion process favours the refractive index modulation. Nevertheless a high quantity of potassium bromide, tends to increase the amount of light scattered by the final hologram. Therefore it is necessary to adjust the values of the ratio B/A nedeed to obtain high diffraction efficiencies and low values of scattering. In the experiments the B/A ratio took the values 2, 8, 30 and 120.

Figure 1 shows the results of peak diffraction efficiency versus B/A ratio for Slavich PFG-01 plates developed with four different developers (D-19, AAC, PAAP and CW-C2). It can be seen from the figure that the optimum B/A ratio for Slavich PFG-01 plates varies when different developers are used in the procedure. A peak diffraction efficiency of 71% (corrected for take into account Fresnel losses) was obtained for a B/A ratio of 120 if the plates were developed in CW-C2; 65% for the AAC developer and a B/A ratio of 8; 64% for plates developed in D-19 for a B/A ratio of 2, and 69% for the PAAP developer and a bleach bath with B/A = 2. It is also interesting to note that for the CW-C2 the ratio at which maximum diffraction efficiency is achieved is the highest (B/A = 120), whereas for the other developers the B/A ratios yielding peak diffraction efficiency are lower (2 or 8). This is due to the hardening of the gelatin created by the oxidation products of the CW-C2 developer during the development step. The hardening of the gelatin makes diffusion of the silver ion from the exposed to the unexposed zones difficult [8, 9], so higher concentrations of potassium bromide are needed in order to improve the diffusion mechanism. The oxidation products of AAC and PAAP developers, on the other hand, do not create a tanning action, therefore such high B/A ratios are not needed. With respect to the D-19 developer, it should be pointed out that the oxidation products of this developer do not create a tanning action during the development step, since due to the high content of sulfite in the solution, this tanning action occurs during the bleach bath. It is clear that the B/A ratio must be adjusted carefully for the particular developer which is used in the development step. Nevertheless values of diffraction efficiency of over 50% are maintained for all developers and B/A ratios.

Figure 2 shows diffraction efficiency versus exposure for plates yielding peak diffraction efficiency with the four different developers used. The highest values of diffraction efficiency were achieved with plates developed in PAAP and CW-C2 developers. However, the behavior of plates developed in CW-C2 is better, because the response of diffraction efficiency versus exposure is almost flat for values of exposure ranging from 125 to 5500 $\mu J/cm^2$, with a diffraction efficiency of over 60% being maintained. With respect to plates developed in PAAP developer, it can be seen that the curve of diffraction efficiency versus exposure has two different maximums separated by a deep trough. As will be seen later this behavior is due to excess refractive index modulation.

Figures 3 and 4 shows diffraction efficiency versus exposure for plates developed in the four different developers and bleached with the 4 different B/A ratios. For both AAC and D-19 developer, the value of exposure yielding peak diffraction efficiency is displaced to the zone of low exposures as the B/A ratio increases. This is due to the fact that a low B/A ratio, implies a higher degree of hardening of the gelatin and a lower concentration of potassium bromide, which makes the diffusion mechanism created inside the emulsion from the exposed to the unexposed zones difficult; therefore higher exposures are needed as the B/A ratio decreases. On the other hand it should be pointed out that the best behavior of diffraction efficiency versus exposure is obtained when the plates are developed in CW-C2 developer.

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The response of diffraction efficiency versus exposure is almost flat for the different B/A ratios (except for a B/A ratio of 8).

Measurements were also made of the scattered light intensity using the setup shown in Figure 5. The light coming from a He-Ne laser impinged onto the hologram forming an angle of 22.5° (Bragg angle in air) with the normal to the holographic grating. The light scattered by the holographic grating diffused away and was made to collect onto a photo-detector by using a lens. The absolute values of the scattered light intensity were not measured, because only part of the total amount of light scattered by the hologram impinged on the lens. Nevertheless, the values of the intensity measured by the photodetector gave comparative information of the amount of light scattered by the different holograms. In Figure 6 the values of scattered light intensity (in arbitrary units) versus exposure are shown for the different B/A ratios. It can be seen from the resulting figures that the response of scattering versus exposure is similar for the different B/A ratios, with an increase in scattering as the values of exposure increase. The scattered light intensity also increases as the B/A ratio is increased. Nevertheless, for plates developed with CW-C2, the scattered light intensity is lower than the scattering with the other plates.

4.2.- Angular response of the transmittance

The efficiency of the diffracted and the transmitted beams, η and τ, respectively, together with the absorption of the material αd (where α is the absorption coefficient and d is the thickness of the photographic emulsion after processing) are three parameters that may be used to characterize holographic transmission gratings recorded on the silver halide sensitized gelatin of Slavich PFG-01 plates. By means of Kogelnik's coupled wave theory [16], it is possible to obtain an analytical expression for the diffraction efficiency of volume

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holograms. As Kogelnik's theory is limited o the description of two diffraction orders, then [17]:

$$\tau = \exp(-\alpha d/\cos\theta') - \eta \quad (5)$$

where τ is the transmission of the hologram and η is given as in equation (1).

We tested the holograms by rotating them, and the variation in transmission with the angle of incidence τ in air was measured. The rotation axes stayed in the plane of the hologram and was perpendicular to the plane of incidence. The values of transmission were corrected to take into account Fresnel's reflections and the absorption of the glass substrate. By fitting the theoretical function (equation (5)) to the experimental data we obtained information about the refractive index modulation, the thickness and the absorption coefficient.

Figure 7 shows the product $\Delta n \cdot d$ as a function of exposure for plates developed with the four different developers yielding peak diffraction efficiency. The discontinuous line corresponds to the value of $\Delta n \cdot d$ which allows maximum diffraction efficiency to be reached ($\nu = \pi/2$). It can be seen that the refractive index modulation reaches higher values than this product when the plates are developed in AAC and PAAP. This excess modulation is the reason for the troughs seen in the corresponding diffraction efficiency versus exposure curves. For instance, in the case of the diffraction gratings developed with AAC and bleached with a B/A ratio of 8, the minimum value of the diffraction efficiency was obtained for a value of the exposure of 1000 $\mu J/cm^2$ and corresponds to a high value of the product $\Delta n \cdot d$ of 0.536 μm. This value of $\Delta n \cdot d$ yields to a value of ν of 2.737 corresponding to a low maximum achievable diffraction efficiency of 16%. For this value of the exposure the

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measured diffraction efficiency was only of 3%, because the absorption and scattering was high, 50%. Therefore it is clear that an excessive increase of the product $\Delta n \cdot d$ over the value of 0.31 μm could lead to a decrease of the diffraction efficiency. For plates developed with D-19 (bleached with a B/A ratio of 2) the value $\Delta n \cdot d = 0.31$ μm is never reached, whereas for plates developed with CW-C2 the product $\Delta n \cdot d$ is kept near 0.31 μm for values of exposure ranging from 125 to 3700 μJ/cm^2. In fact, the values of $\Delta n \cdot d$ are kept within the range 0.217 μm $\leq \Delta n \cdot d \leq$ 0.399 μm for these range of exposures, which means that the values of ν are kept within $1.108 \leq \nu \leq 2.037$ and the theoretical diffraction efficiency that can be achieved is $\eta_{max} \geq 80\%$; these values are limited by absorption and scattering and the measured diffraction efficiency is kept over $\eta \geq 60\%$. Therefore, the fact that the product $\Delta n \cdot d$ is kept near 0.31 μm for values of exposure ranging from 125 to 3700 μJ/cm^2, explains the flat response of diffraction efficiency versus exposure for plates developed with CW-C2 and bleached with a B/A ratio of 120.

4.3.- Excess of modulation effects

As can be seen in the previous section, fixation-free bleaching techniques are efficient enough to create high refractive index modulations. This excess modulation will yield a decrease in diffraction efficiency when the value of $\nu = \pi/2$ is surpassed. In order to compare the effects of this excess modulation in the response of the diffraction efficiency as a function of the exposure and in the angular response of the transmittance, two series of plates were chosen. Figures 8 and 9 correspond to plates developed with AAC and bleached with a B/A ratio of 2, whereas Figures 10 and 11 correspond to plates developed with PAAP and bleached with a B/A ratio of 8. In the first case (plates developed with AAC) the values

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of the product Δn·d obtained were not very high, whereas in the second case (plates developed with PAAP) the values of the product Δn·d are high. Figure 8 shows the value of the product Δn·d and diffraction efficiency as a function of exposure for plates developed with AAC and bleached at a B/A ratio of 2. The flat response of diffraction efficiency versus exposure for values of exposure ranging from 100 to 5500 μJ/cm^2 is due to the fact that the product Δn·d is kept near 0.31 μm for this range of exposures, as explained in the case of plates developed with CW-C2 and bleached with a B/A ratio of 120. Figure 9 shows transmittance versus angle of reconstruction for four different exposures (125, 290, 700 and 1550 μJ/cm^2) for plates developed with AAC and bleached at a B/A ratio of 2. There are two troughs centered at -22.5° and 22.5°, which are the Bragg angles. The depth of these troughs determine the value of the diffraction efficiency, measured at Bragg angle. For exposures of 290 and 700 μJ/cm^2, yielding a slight excess of modulation, the adjacent troughs are slightly deeper than those corresponding to exposures of 125 and 1550 μJ/cm^2. Nevertheless the depth of the troughs centered at Bragg angle is still high, so that the values of the diffraction efficiency are kept high.

Figure 10 shows the value of the product Δn·d, and the diffraction efficiency as a function of exposure for plates developed with PAAP and bleached at a B/A ratio of 8. For exposures ranging from 190 to 700 μJ/cm^2 the value of 0.31 μm is surpassed, with values of 0.493 μm for an exposure of 190 μJ/cm^2 and 0.496 μm for an exposure of 440 μJ/cm^2 being reached. These high values of the product Δn·d correspond to a considerable decrease in the diffraction efficiency. Figure 11 shows the transmittance versus the angle of reconstruction for four different exposures (125, 290, 700 and 1550 μJ/cm^2) for plates developed with PAAP and bleached at a B/A ratio of 8. It is clear that the increase in modulation corresponds to an increase in the depth of the troughs adjacent to the two centered at the Bragg angles, with the corresponding decrease in diffraction efficiency at the Bragg angle (depth of the troughs centered at Bragg angle). Therefore it has been demonstrated that the high values of the product $\Delta n \cdot d$ obtained with plates developed with PAAP developer and bleached with a B/A ratio of 8 are the real cause of the decrease in diffraction efficiency shown in the diffraction efficiency versus exposure curves for these plates.

5.- Conclusions

A fixation-free rehalogenating bleach based on a modified version of the R-10 has been optimized for Slavich PFG-01 plates by using different developers (D-19, CW-C2, AAC and PAAP). It has been demonstrated that the optimum B/A ratio, determining the relation between the potassium bromide concentration and the oxidizer concentration, depends on the developer used. A peak diffraction efficiency of 71% was obtained for a B/A ratio of 120 when the plates were developed in CW-C2; 65% for the AAC developer by bleaching the plates with a B/A ratio of 8; 64% for plates developed in D-19 for a B/A ratio of 2, and 69% for plates developed with PAAP developer and bleached with a B/A ratio of 2. The best results were obtained using the CW-C2 developer -diffraction efficiency of 71% for a B/A ratio of 120-. Also the behavior of PFG-01 plates developed with CW-C2 is better, giving a flat response of diffraction efficiency versus exposure for the different B/A ratios. It has also been demonstrated that the diffusion mechanism that takes place from the exposed to the unexposed zones is efficient enough to create high refractive index modulations, even yielding an excess of modulation effects with a decrease in diffraction efficiency for high values of the product $\Delta n \cdot d$.

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FIGURE CAPTIONS

Figure 1.- Diffraction efficiency versus B/A ratio, under the Bragg condition for transmission gratings recorded on Slavich PFG-01 plates developed with 4 different developers (D-19, CW-C2, AAC, PAAP) and bleached with R-10 at 50°C at 4 different B/A ratios: 2, 8, 30, 120.

Figure 2.- Diffraction efficiency versus exposure, under the Bragg condition for transmission gratings recorded on Slavich PFG-01 emulsion yielding peak diffraction efficiency.

Figure 3.- Diffraction efficiency versus exposure, under the Bragg condition for transmission gratings recorded on Slavich PFG-01 plates developed with D-19 and CW-C2 developers and bleached with R-10 at 50°C at 4 different B/A ratios: 2, 8, 30, 120.

Figure 4.- Diffraction efficiency versus exposure, under the Bragg condition for transmission gratings recorded on Slavich PFG-01 plates developed with AAC and PAAP developers and bleached with R-10 at 50°C at 4 different B/A ratios: 2, 8, 30, 120

Figure 5.- Experimental set-up for the measurement of scattered radiation.

Figure 6.- Variation of scattering with exposure for transmission gratings recorded on Slavich PFG-01 plates developed with 4 different developers (D-19, CW-C2, AAC, PAAP) and bleached with R-10 at 50°C at 4 different B/A ratios: 2, 8, 30, 120.

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Figure 7.- Product of refractive index modulation and thickness ($\Delta n \cdot d$) as a function of exposure for diffraction gratings recorded on Slavich PFG-01 yielding peak diffraction efficiency.

Figure 8.- Product of refractive index modulation and thickness ($\Delta n \cdot d$), and diffraction efficiency as a function of exposure for diffraction gratings recorded on Slavich PFG-01 developed with AAC developer and bleached at a B/A ratio of 2.

Figure 9.- Transmittance versus angle at reconstruction for unslanted phase transmission gratings recorded on Slavich PFG-01 developed with AAC developer and bleached at a B/A ratio of 2.

Figure 10.- Product of refractive index modulation and thickness ($\Delta n \cdot d$), and diffraction efficiency as a function of exposure for diffraction gratings recorded on Slavich PFG-01 developed with PAAP developer and bleached at a B/A ratio of 8.

Figure 11.- Transmittance versus angle at reconstruction for unslanted phase transmission gratings recorded on Slavich PFG-01 developed with PAAP developer and bleached at a B/A ratio of 8.

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TABLE I

Processing schedule

1.- Develop	5 min
2.- Rinse in running water	1 min
3.- Bleach for 1 min after the plate has cleared	
4.- Rinse in running water	5 min
5.- Dry at room temperature	

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TABLE II

Developers formulas

D-19 Developer	
Metol	2 g
Sodium sulfite	45 g
Hydroquinone	8 g
Sodium carbonate (anhydrous)	50 g
Potassium bromide	5 g
Distilled water	1 liter
Developer time	5 minutes at 20°C
AAC Developer[a]	
Ascorbic acid-L	18 g
Sodium carbonate (anhydrous)	60 g
Distilled water	1 liter
Developer time	4 minutes at 20°C
[a]Two solutions, one containing the sodium carbonate and the other containing the ascorbic acid.	
CW-C2 Developer[b]	
Catechol	10 g
Ascorbic acid-L	5 g
Sodium sulfite (anhydrous)	5 g
Urea	50 g
Sodium carbonate	30 g
Distilled water	1 liter
Developer time	2 minutes at 20°C
[b]Two solutions, one containing the sodium carbonate and the other containing the rest of components.	
PAAP Developer	
Phenydone	0.5 g
Ascorbic acid-L	18 g
Sodium hydroxide	12 g
Sodium phosphate	28.4 g
Distilled water	1 liter
Developer time	4 minutes at 20°C

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TABLE III

Bleach bath compositions

Solution A	
Potassium dichromate	20 g
Sulfuric acid	15 ml
Distilled water	1 liter
Solution B	
Potassium bromide	100 g
Distilled water	1 liter

Just before use, mix 1 part A with 10 parts distilled wate; then add X parts B (B/A = X).

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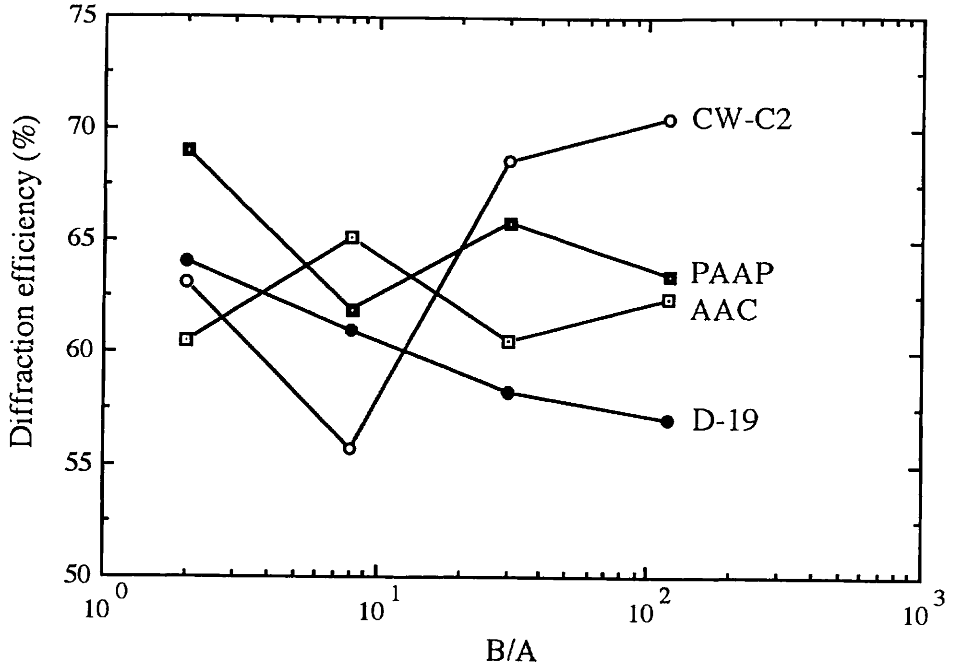

FIGURE 1
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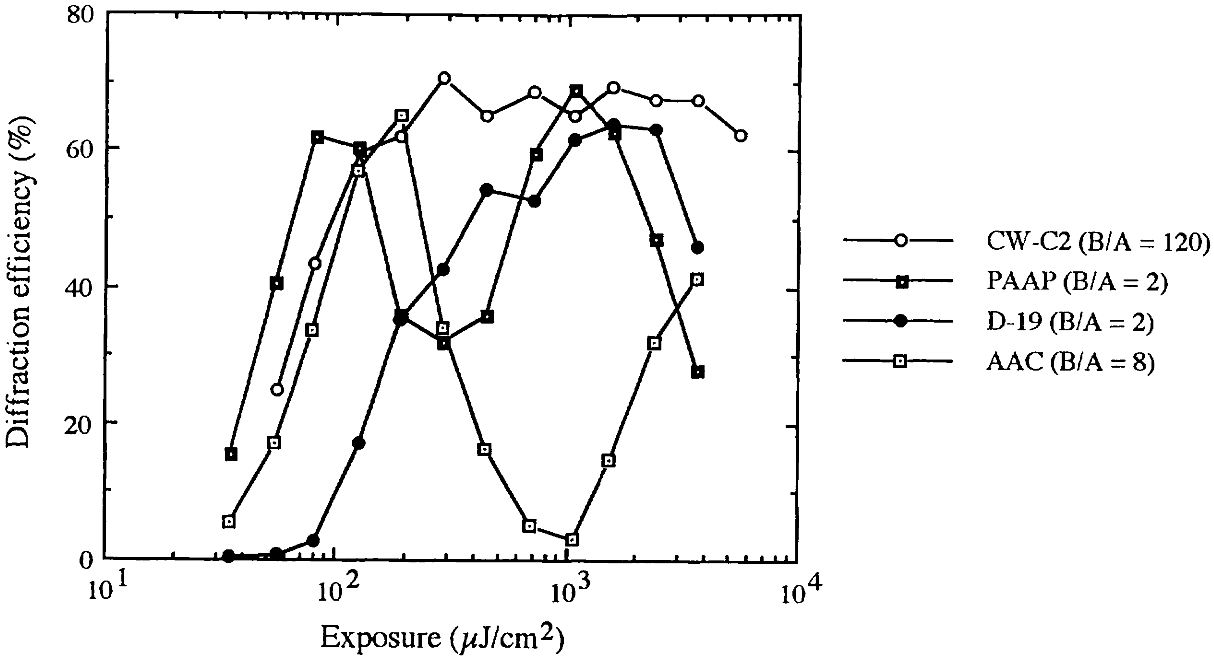

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FIGURE 2
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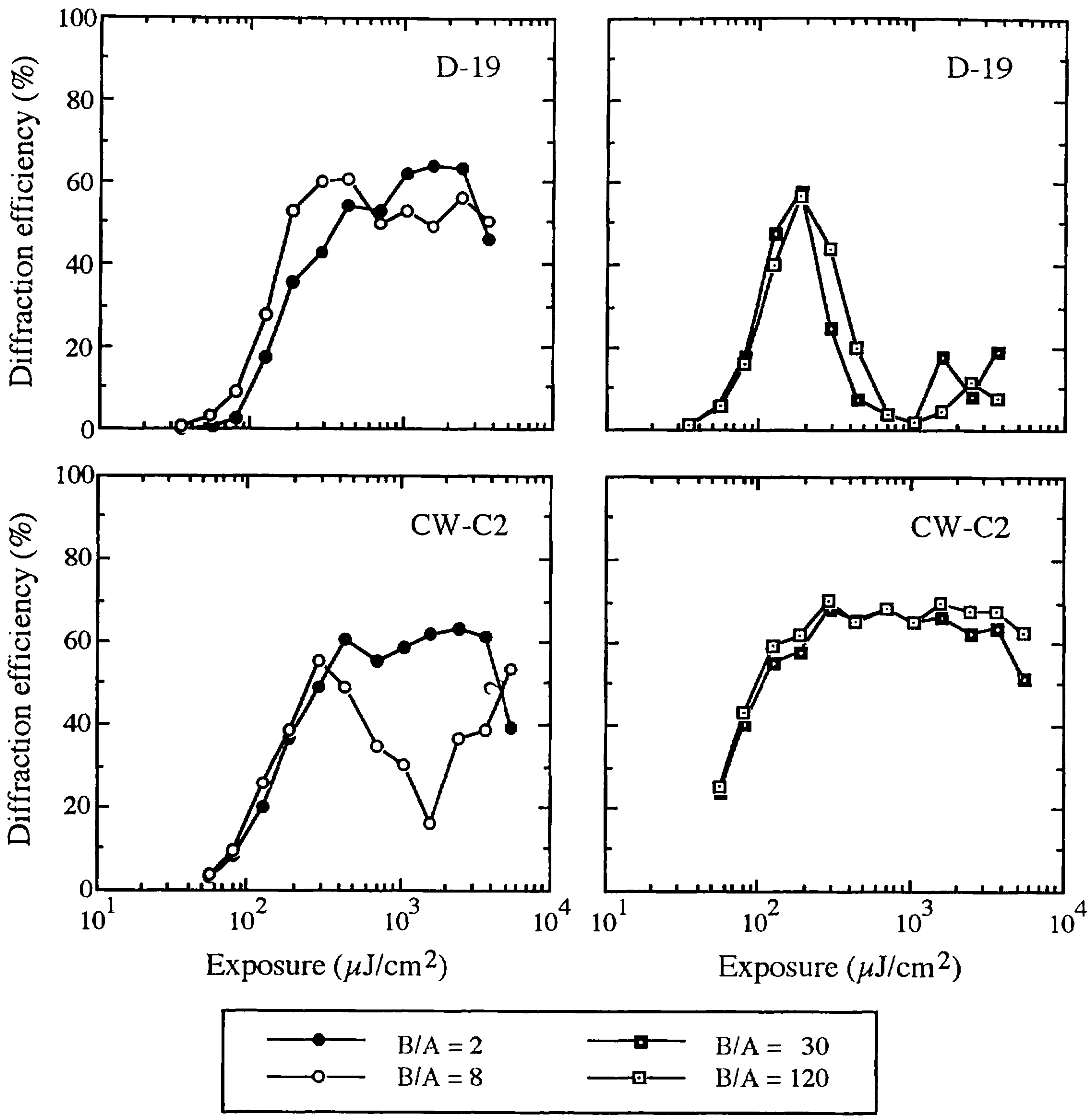

FIGURE 3
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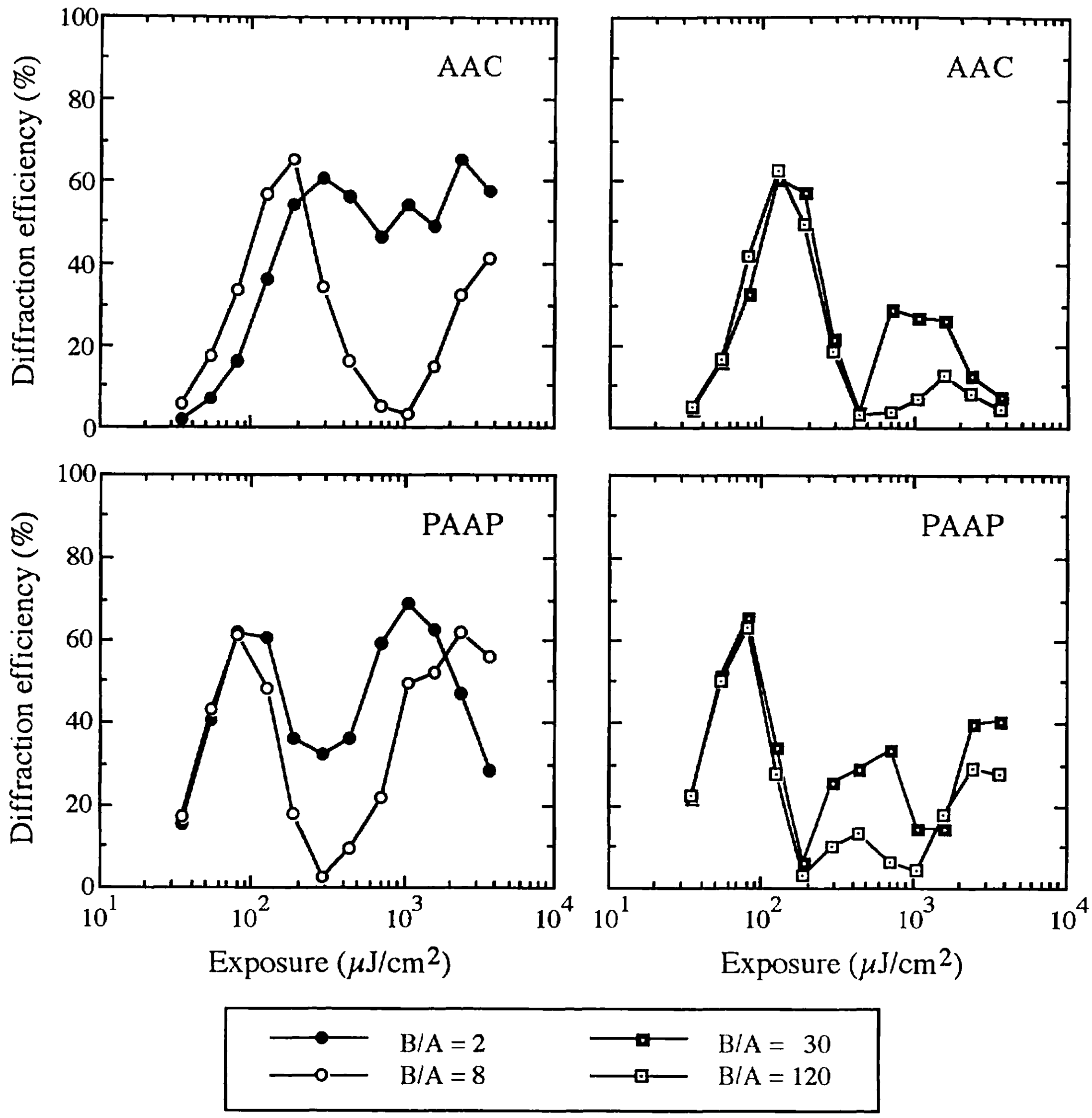

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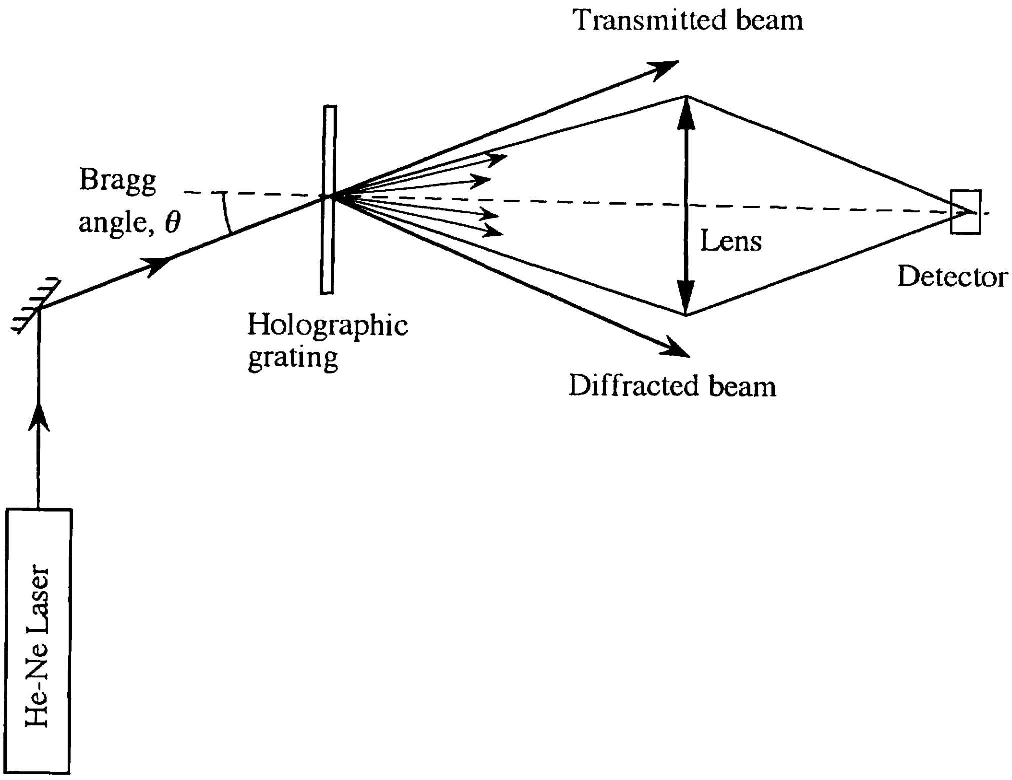

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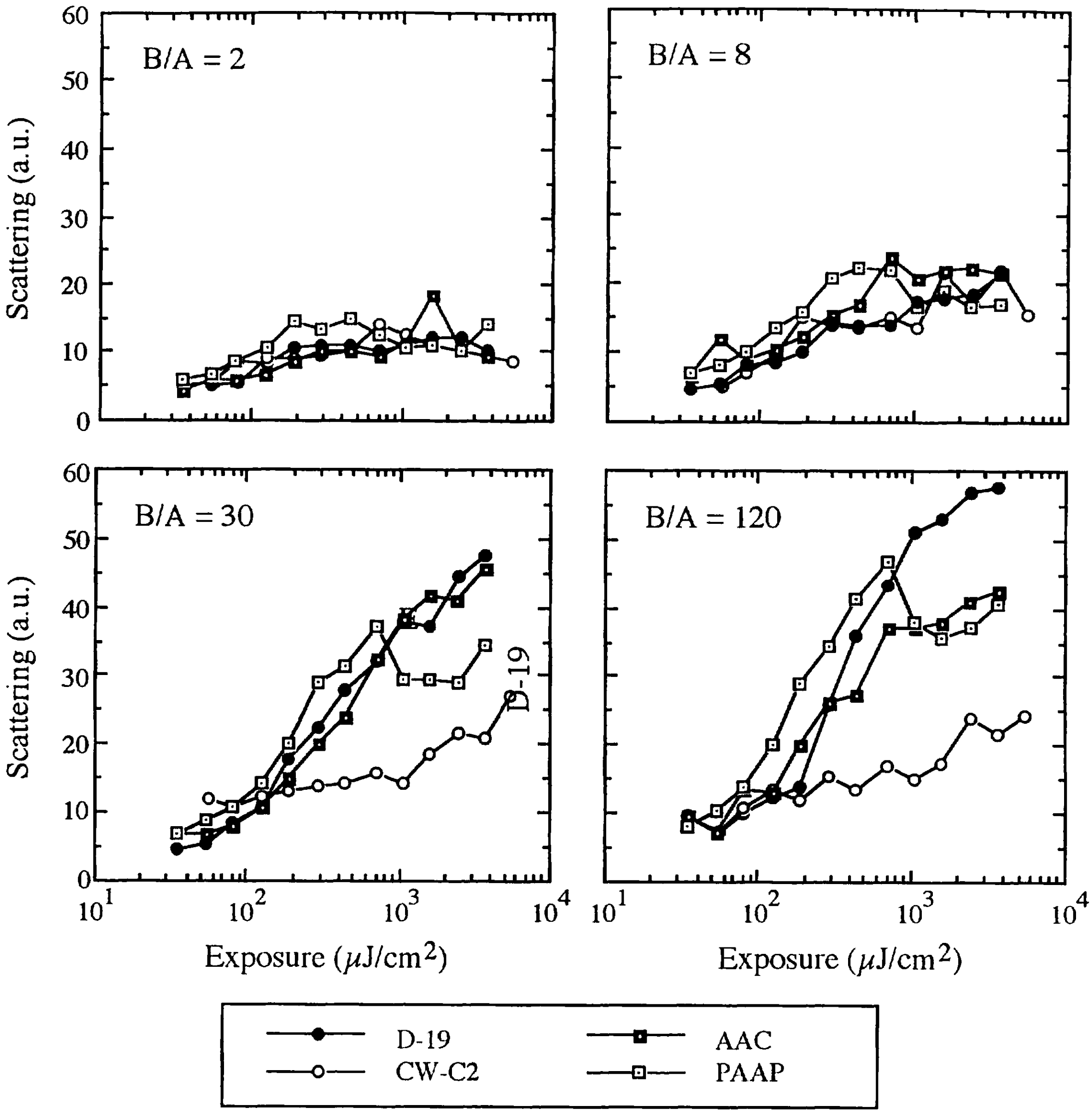

FIGURE 6
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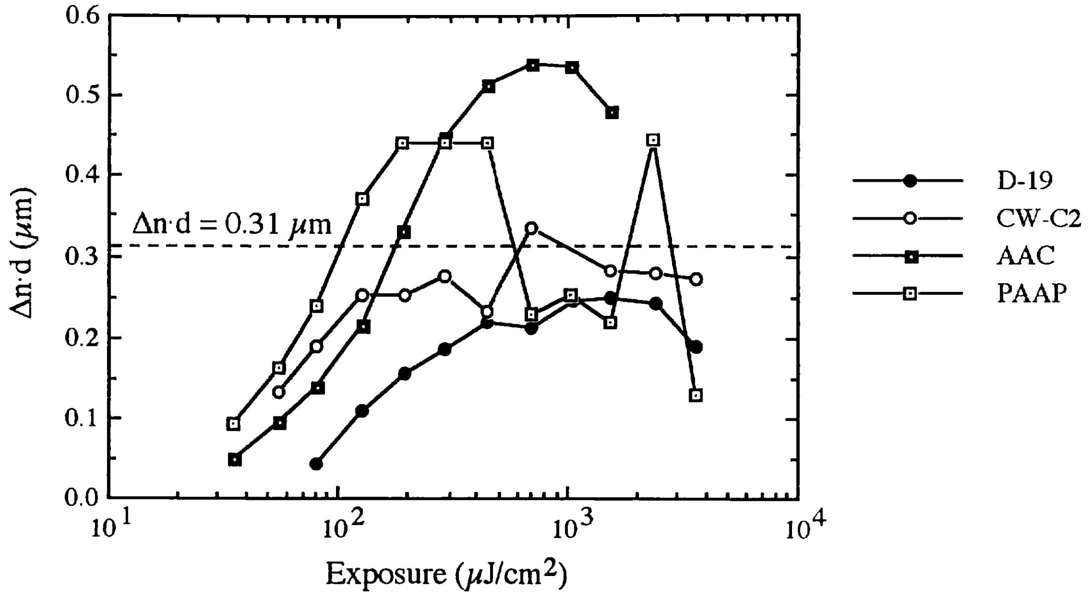

FIGURE 7
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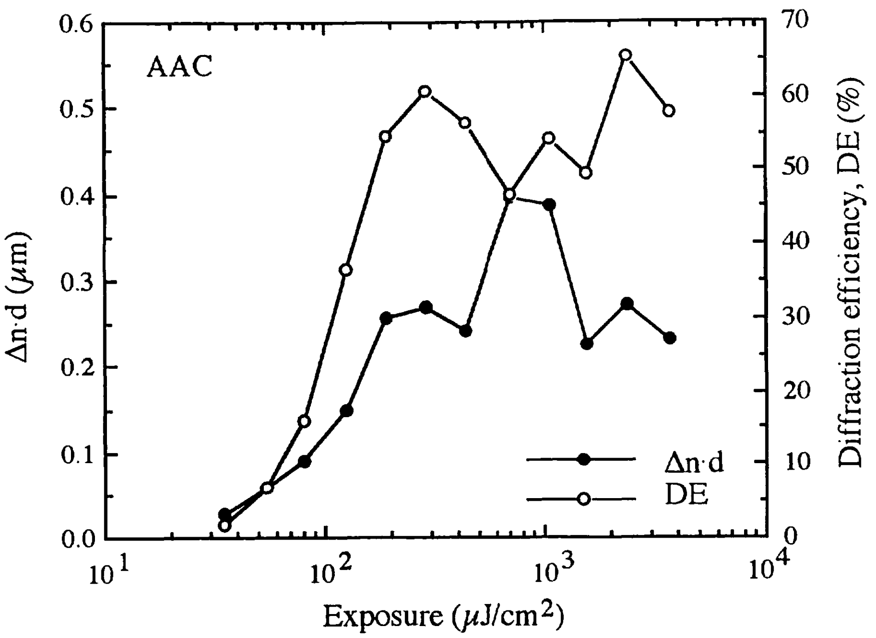

FIGURE 8
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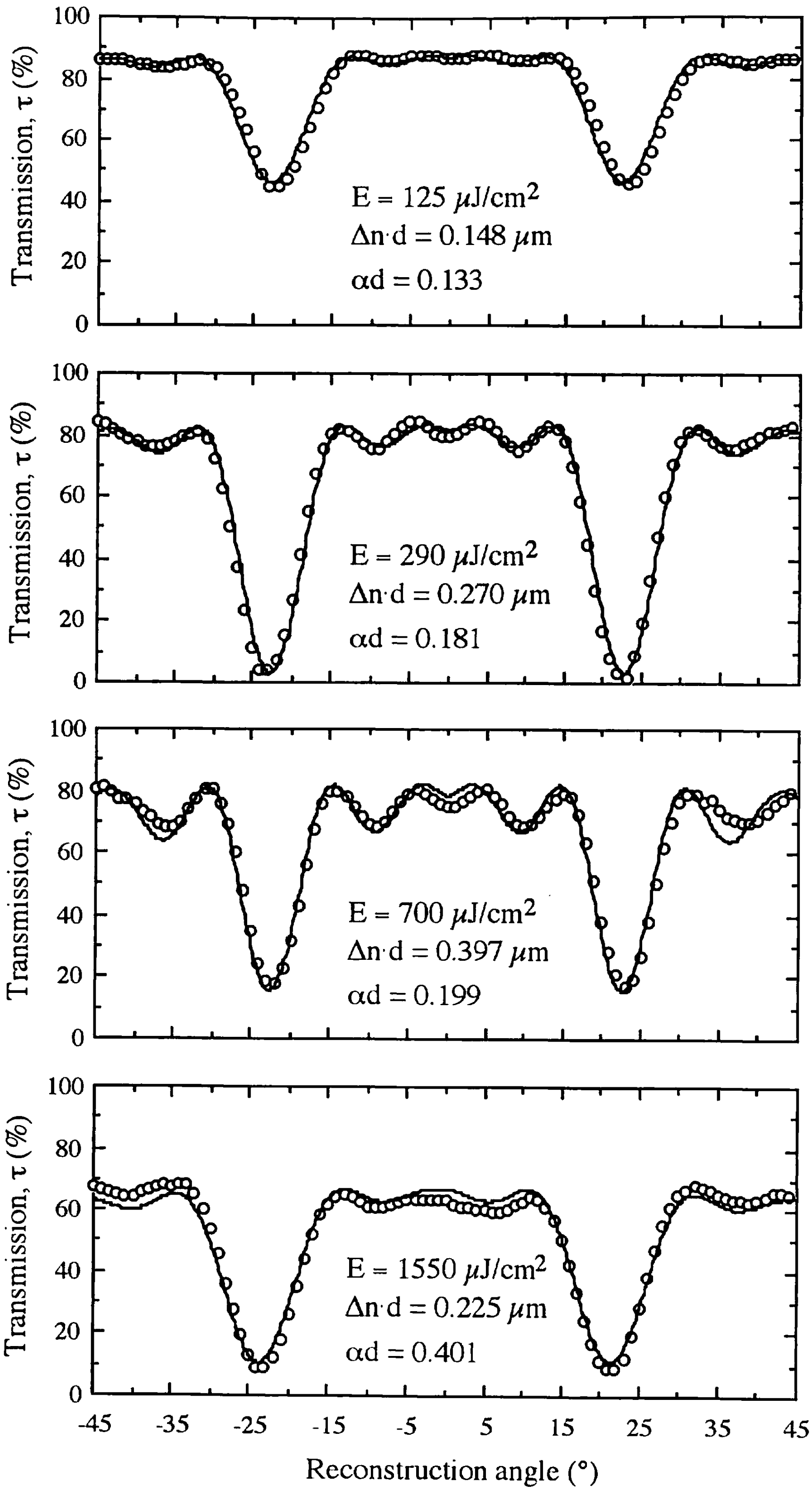

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FIGURE 9
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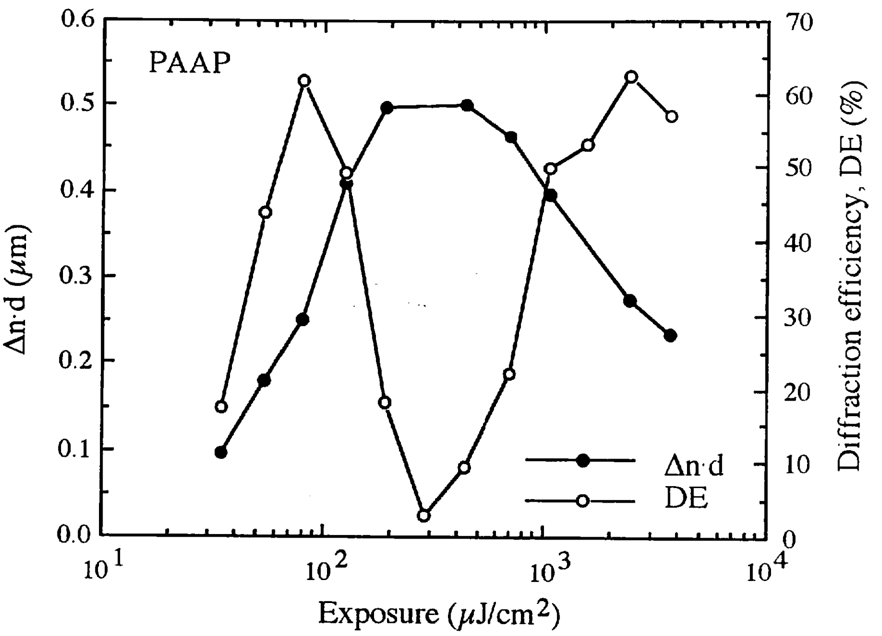

FIGURE 10
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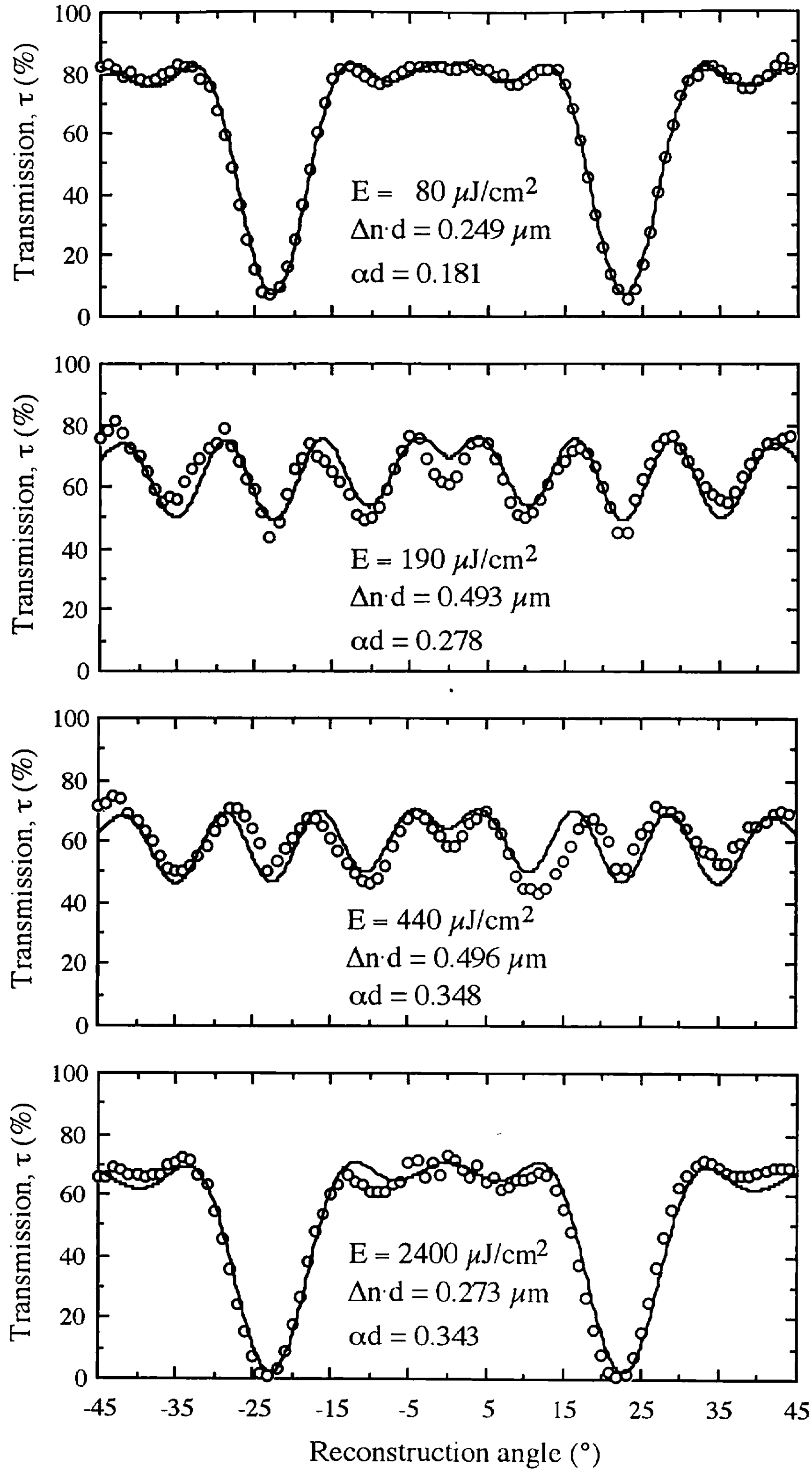

FIGURE 11
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