Optica Applicata, Vol. XXVIII, No. 2, 1998

Letter to the Editor

Computer modelling of modulation transfer function and characteristic curve of AgHal light-sensitive layers containing a dye*

Leszek Latacz, Piotr Nowak

Institute of Physical and Theoretical Chemistry, Wrocław University of Technology, Wybrzeże Wyspiańskiego 27, 50–370 Wrocław, Poland.

Results of computer simulations of light diffusion and absorption in hypothetical silver halide light-sensitive layers containing various amounts of a dye are presented. A stochastic computer model is based on a Monte Carlo method [1]–[5]. Appropriate modification of this method allows us to determine an optical modulation transfer function of the layer and a vertical distribution of light absorbed by silver halide in the presence of dye [6], [7]. Isotropic scattering of light is assumed for Ag-Hal crystals. A simple model of characteristic curve [8] is utilized for analysis of a dependence of basic sensitometric parameters on the relative dye concentration. General structurometric advantages and sensitometric disadvantages of the dye addition in a heterogeneous light-sensitive layer are discussed.

1. Introduction

The aim of this paper is to discuss the influence of dye addition on the optical modulation transfer function and sensitometric parameters of a model AgHal light-sensitive layer. A Monte Carlo method allows us to determine spatial distribution of effective exposure inside the model layer and to calculate the modulation transfer function. Combining vertical distribution of effective exposure and model characteristic curve of elementary layer makes it possible to determine a composite characteristic curve and to assess basic sensitometric characteristics.

2. Assumptions in the Monte Carlo method

The model is based on the following assumptions:

– There is no protective layer over the AgHal emulsion.

– There is an ideal antihalation undercoat beneath the layer.

– Photons enter the layer perpendicularly to the surface (along z axis).

– Probability that a photon which collides with an emulsion grain is absorbed equals 0.005.

– Elementary indicatrix of scattering is spherical.

– Mean free path length of photon $\langle l_p \rangle$ between collisions with grains equals 1.0 μm.

---

* This paper has been presented at the Poster Session of the International Congress on Imaging Science, September 7–11, 1998, Antwerp, Belgium.

— Relative concentration of a dye is expressed as a ratio $\langle l_p \rangle / \langle l_d \rangle$, where $\langle l_d \rangle$ is a mean cumulative path length of photon in the layer before absorption by the dye.

3. Assumptions in the characteristic curve model

The assumptions are the following:

— Thick layer consists of a certain number of elementary thin layers.

— Exposures of individual elementary layers q (in quanta per grain size) are given by the vertical distribution of effective exposure H.

— AgHal grains are monosized and quantum sensitivity of grains is constant ($Q = 4$), thus the model characteristic curve of a individual elementary layer is given by the following equation: $D = 1 - \exp(-q)(1 + q + q^2/2 + q^3/6)$.

— Combined characteristic curve of a thick layer is a sum of elementary model curves.

— Maximal density is proportional to the thickness of the layer h (in μm) ($D_{max} = 0.2h$).

4. Results

Results of computer simulations and calculations are depicted in a convenient graphical form. Figures 1 and 2 illustrate the influence of dye addition on light diffusion inside the heterogeneous light-sensitive layer. Figure 3 shows vertical distributions of effective exposure for various thicknesses of the layer and various relative dye concentrations, whereas Fig. 4 shows the corresponding calculated model characteristic curves. Figures 5, 6 and 7 illustrate changes in a run of modulation transfer function caused by the dye addition to layers of various thicknesses.

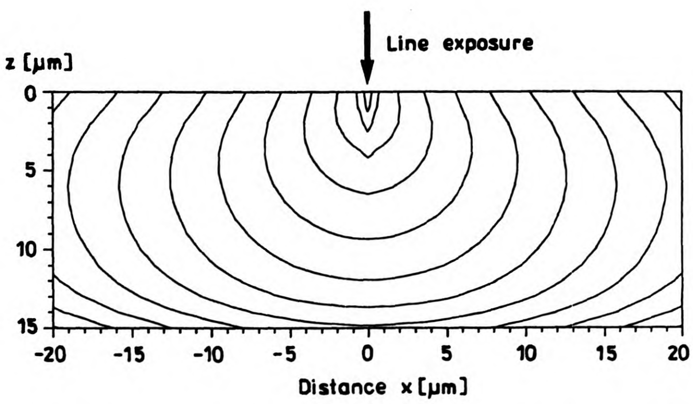


Fig. 1. Spatial distribution of a line exposure inside the layer in the absence of a dye ($C = 0.0$). Successive contours represent $\Delta \mathrm{Log}\ H = 0.3$

Figures 8 and 9 show maximal gradient G and sensitivity S of the layer as functions of thickness of the layer for various dye concentrations. Sensitivity is determined according to fractional gradient criterion. The speed point is the point on

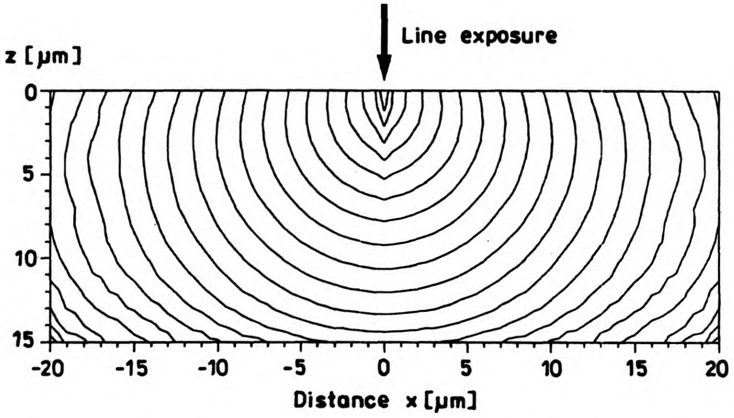
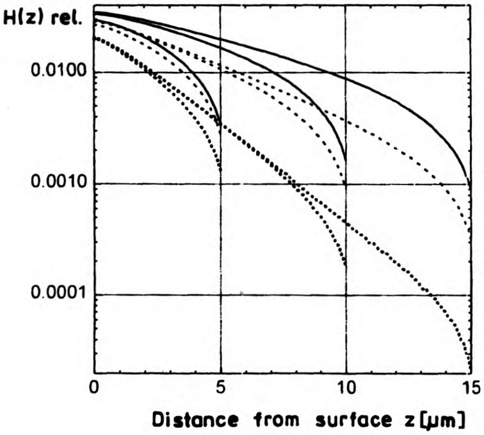
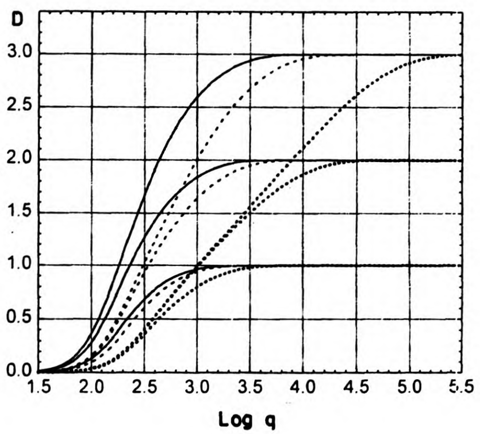


Fig. 2. Spatial distribution of a line exposure inside the layer in the presence of a dye ($C = 0.05$). Successive contours represent $\Delta \mathrm{Log}\ H = 0.3$



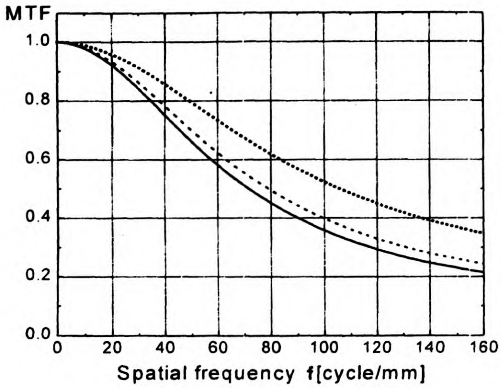


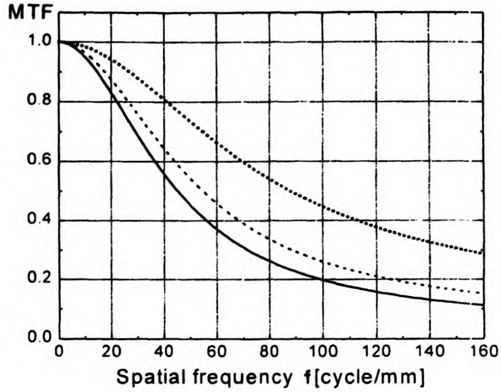
▲

Fig. 3. Vertical distribution of effective exposure for layer thicknesses $h = 5$, 10 and 15 µm and for various dye concentrations. Solid line – no dye, dashed line – $C = 0.01$, dotted line – $C = 0.05$

Fig. 4. Model characteristic curves for layer thicknesses $h = 5$, 10 and 15 µm and for various dye concentrations. Solid line – no dye, dashed line – $C = 0.01$, dotted line $C = 0.05$

the characteristic curve at which fractional gradient $FG = 0.25G$ is first reached. The logarithmic speed $S = (4 - \mathrm{Log} q_s) \times 10$, where q_s is the exposure at the speed point. Figure 10 shows the dependence of a limit spatial frequency $f_{0.3}$ on dye concentration C for various thicknesses of the layer. The limit spatial frequency $f_{0.3}$ is the frequency at which the value of modulation transfer function equals 0.3.





▲

Fig. 5. Modulation transfer function (MTF) for layer thickness $h = 5\,\mu m$ and for various dye concentrations. Solid line – no dye, dashed line – $C = 0.01$, dotted line – $C = 0.05$.

Fig. 6. Modulation transfer function (MTF) for layer thickness $h = 10\,\mu m$ and for various dye concentrations. Solid line – no dye, dashed line – $C = 0.01$, dotted line – $C = 0.05$

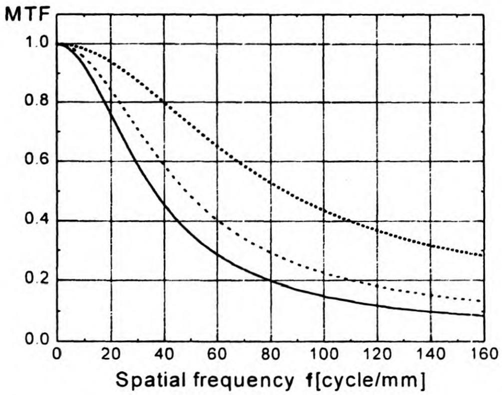


Fig. 7. Modulation transfer function (MTF) for layer thickness $h = 15\,\mu m$ and for various dye concentrations. Solid line – no dye, dashed line – $C = 0.01$, dotted line – $C = 0.05$

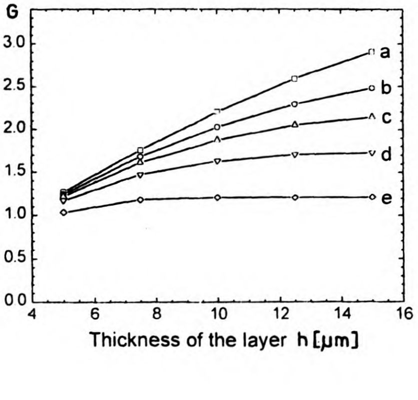


Fig. 8. Maximal gradient G as a function of thickness of the layer h for various dye concentrations: **a** – no dye, **b** – $C = 0.005$, **c** – $C = 0.01$, **d** – $C = 0.02$, **e** – $C = 0.05$.

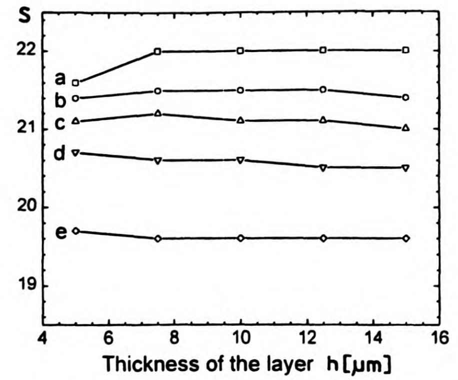


Fig. 9. Sensitivity S as a function of thickness of the layer h for various dye concentrations: **a** – no dye, **b** – $C = 0.005$, **c** – $C = 0.01$, **d** – $C = 0.02$, **e** – $C = 0.05$

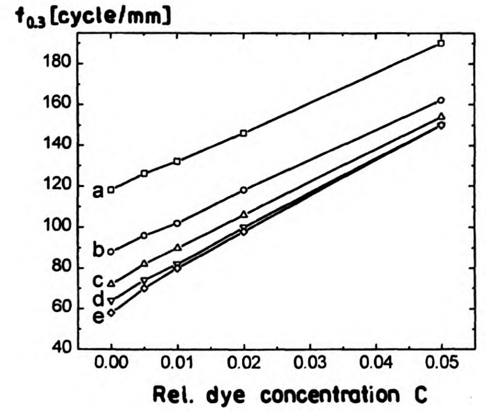


Fig. 10. Limit spatial frequency $f_{0.3}$ as a function of dye concentration C for various thicknesses of the layer: **a** – $h = 5.0$ μm, **b** – $h = 7.5$ μm, **c** – $h = 10.0$ μm, **d** – $h = 12.5$ μm, **e** – $h = 15.0$ μm

5. Conclusions

The dye addition to the heterogeneous light-sensitive layer causes significant decrease of light diffusion. Hence, the optical modulation transfer is highly improved, particularly in the case of a relatively thick layer. The main disadvantage of the dye addition is that the slope of characteristic curve decreases. But, on the other hand, an increase of latitude can be an advantage for continuous tone photographic materials. Surprisingly, the dependence of sensitivity on the concentration of dye is relatively weak.

Acknowledgements – The work was supported by the Wrocław University of Technology Grant No. 341633.

References

[1] DE BELDER M., DEKERF M., JESPERS J., VERBRUGGHE R., J. Opt. Soc. Am., **55** (1965), 1261.

[2] DE PALMA J. J., GASPER J., Phot. Sci. Eng. **16** (1972), 181.

[3] WOLFE R. N., MARCHAND W., DE PALMA J. J., J. Opt. Soc. Am. **58** (1968), 1245.

[4] LOHMANN J., METZ H. J., J. Inf. Rec. Mats. **22** (1994), 183.

[5] LATACZ L., NOWAK P., *Modelling of the modulation transfer function of linear systems for optical systems for recording of image information*, (in Polish), Proc. of II Local Conf. KOWBAN, Wrocław, December 1995, pp. 203–209.

[6] LATACZ L., NOWAK P., *Modelling of exposure distribution inside the heterogenic light-sensitive layers*, (in Polish), Proc. of III Local Conf. KOWBAN, Wrocław–Polanica Zdrój, October 1996, pp. 135–140.

[7] LATACZ L., NOWAK P., *Modelling investigations of the screening dye influence on the modulation transfer function for silver halide light-sensitive layers*, (in Polish), Proc. of IV Local Conf. KOWBAN, Wrocław–Świeradów Zdrój, October 1997, pp. 137–141.

[8] DAINTY J. C., SHAW R., *Image Science. Principles, Analysis and Evaluation of Photographic-Type Imaging Processes*, Academic Press, London, New York, San Francisco 1974, pp. 76–96, 260–263.

Received April 28, 1998