The Regression of the Centers of the Latent Photographic Image

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The time dependence of the regression of the centers of the latent photographic image and the subcenters has been investigated. It has been shown that the regression process is subject to a law similar to that of the relaxation of photo-conductivity and the damping of luminescence in crystals of silver halide.

THE regression of the centers of the latent image in plates with thick emulsion strata is manifested in the fact that the capacity for the development of emulsion crystals which have been subjected to the action of ionizing particles [1,2] or light [3] gets reduced in accordance with the length of time of storage.

The analogous effect, in such an ostensible form, is, however, not observed in the ordinary photographical plates. In their emulsion layers the centers of the latent image are more stable and regress but little with the passing of time. The same centers of the latent image in the case of the development delayed over some period of time after the cessation of light action are less stable and subject to apparent regression. Such centers are often called the subcenters of the latent image.

This work is devoted to the analysis of the regression of the centers of the latent image and the subcenters.

THE METHOD OF EXPERIMENTATION

A definite exposure was given to a photographic plate, either continuous, lasting 100 sec (t_0), or intermittent, dividing the same exposure time into two batches of illumination with a certain dark interval between them.

As the time (t_1) of the first exposure we took 10 sec, 20 sec, 30 sec, and so on. The time (t_2) of the second exposure was accordingly 90 sec, 80 sec, 70 sec, and so on. In each case $t_1 + t_2 = t_0$, or 100 sec. The time τ of the dark interval was changed alternately from 1 to 30 days. Illumination was from an incandescent lamp operated through a light stabilizer.

A sensitometric graphite wedge with the constant of 0.15 for white light and 0.17 for the blue was kept in front of the photographic plate. The development was carried in the Chibisov's developer. The constancy of the temperature of the development with the precision up to 0.5^0 was secured by means of a thermostatic control. The measurements on the resulting sensitograms were taken by means of the photo electric densitometer evaluating the diffusive density (D). The measurements were carried on the diapositive (2^0 H & D), line reproduction (2^0 GOST), and isoorthochromatic (31 units GOST) plates. Through the medium of the sensitograms the characteristic curves of $D = f(\lg H)$ were drawn with $\lg H$ (the value of the logarithm of the quantity of illumination) plotted in relative units.

THE RESULTS OF THE EXPERIMENTS

The comparisons were made of the characteristic curve obtained with the uninterrupted illumination lasting 100 sec with the characteristic curves obtained with this exposure divided into two batches of illumination of different durations, i. e. for various values t_1/t_0.

In all cases the curve of the intermittent illumination was shifted with respect to the curve of the uninterrupted illumination in the direction of greater values of $\lg H$ (Fig. 1). This shift we were e-

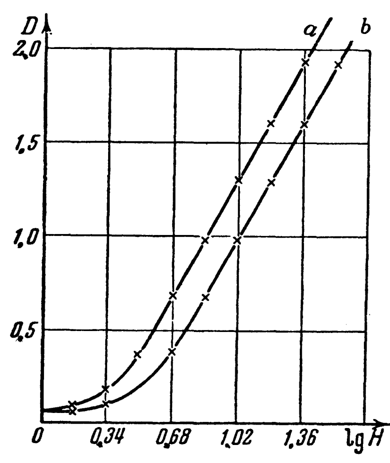

Fig. 1. The characteristic curves of reproduction plates. Curve a - for the uninterrupted illumination; Curve b - for the intermittent illumination; With $t_1/t_0 = 0.5$ and $\tau = 6$ days.

[1] M. Blau, Sitz. Ber. Acad. Wiss. Wien 140, 623 (1931)

[2] H. Farraggi and G. Albouy, Compt. Rend. 226, 717 (1948)

[3] L. Winand and L. Falla, Bull. Roy. Soc. Sci. Liège 18, 184 (1949)

valuating by $\Delta\lg H$ of some definite value of optical density.

In Fig. 2 the relations are shown between $\Delta\lg H$ and t_1/t_0 obtained for the three different dark intervals, for the diapositive plates (for $D = 1$).

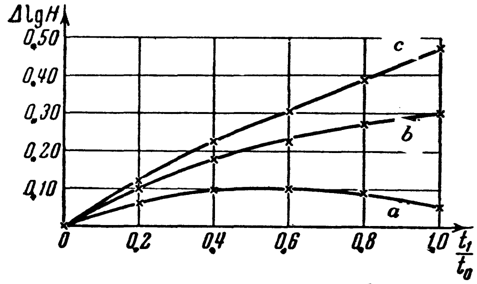

Fig. 2. The curves showing the relation between $\Delta\lg H$ and t_1/t_0 for the diapositive plates (for $D = 1$).
a for $t = 1$ day; b for $t = 6$ days; c for $t = 20$ days

In Fig. 3 the same relations appear for the reproduction plates (for $D = 1.5$). It becomes apparent from the examination of these curves that the regression of the subcenters of the latent image is most prominent for a certain intermediate value (t_1/t_0) max. and that this value of (t_1/t_0) max. increases with the increase in duration of the dark interval τ.

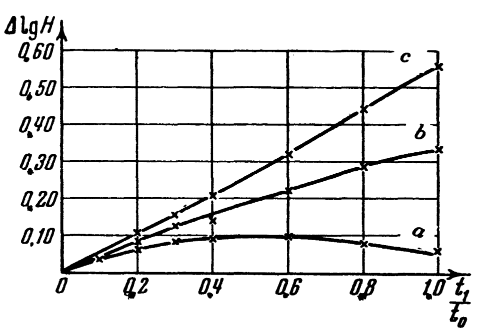

Fig. 3. The curves showing the relation between $\Delta\lg H$ and t_1/t_0 for the reproduction plates (for $D = 1.5$).
a for $t = 1$ day; b for $t = 7$ days; c for $t = 20$ days.

The results of the experiments may be expressed in a somewhat different way. Let H_0 be the quantity of illumination necessary to effect a certain density when the illumination is continuous and the development carried out immediately upon the the exposure , and N_0 be the number of atoms of silver found within the centers of latent image in the emulsion crystals, producing this density, so that $H_0 = CN_0$. If the development takes place after the lapse of time τ upon the exposition, then by that time the number of atoms of silver in the center will be N. Hence the effect of the development would be such as if the quantity of illumination $H = CN$ were in continuous action through an uninterrupted exposure and with development carried out immediately after the exposure. This means that

$$\Delta\lg H = \lg\frac{H_0}{H} = \lg\frac{N_0}{N}.$$

Hence we may write that

$$\frac{N}{N_0} = \frac{1}{\text{anti}\lg(\Delta\lg H)}.$$

Now it is possible to draw some conclusions concerning the mechanism of the regression from the relation existing between N/N_0 and τ.

At the present time there are two theories [4] of the regression. According to the first of these the regression is an effect of the oxidation produced by the oxygen found in the air. It is also commonly accepted that the presence of the vapor of water intensifies this reaction.

According to the second theory the regression is an effect of the combination of atoms of silver found in the latent image with the atoms of bromide. If the first of these two theories is correct, i. e., if the mechanism of the regression is monomolecular, then the number dN of atoms of silver participating in the regression during the interval dt is given by

$$dN = -kN\,dt. \tag{1}$$

If the bromosilver or bimolecular theory is true, then the respective number of atoms of silver participating in the regression is

$$dN = -kN^2\,dt. \tag{2}$$

In both cases k is the coefficient of proportionality.

The root of the first equation will be

$$N/N_0 = e^{-k\tau}, \tag{3}$$

and of the second,

$$N/N_0 = (1 + N_0 k\tau)^{-1}. \tag{4}$$

The experiments prove that neither of these two equations is true. As an illustration Figures 4 and

[4] H. Farraggi and G. Albouy, *Photographic Registration of Ionic Radiations*, 223

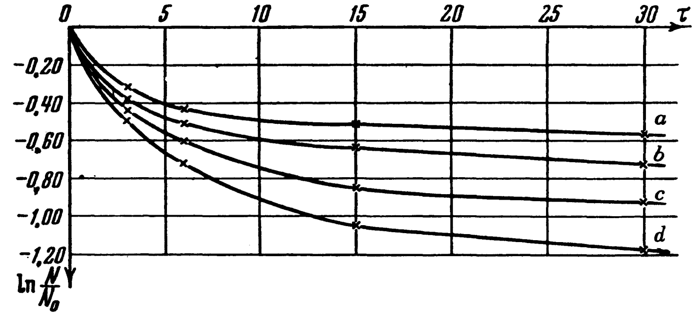

Fig. 4. The curves showing the relation between ln (N/N_0) and τ for the diapositive plates. The curve *a* for $t_1/t_0 = 0.4$; *b* for $t_1/t_0 = 0.6$; *c* for $t_1/t_0 = 0.8$; *d* for $t_1/t_0 = 1.0$

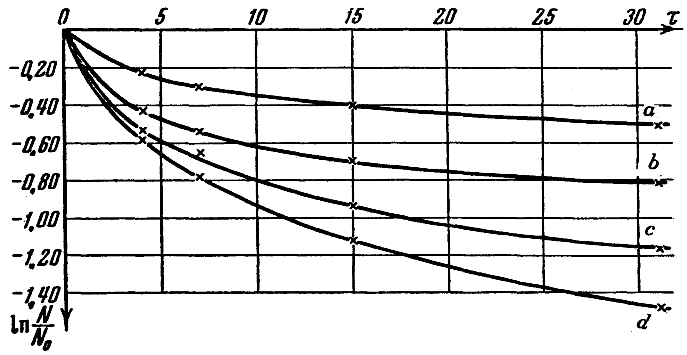

Fig. 5. The curves showing the relation between ln (N/N_0) and τ for the reproduction plates. The curve *a* for $t_1/t_0 = 0.4$; *b* for $t_1/t_0 = 0.6$; *c* for $t_1/t_0 = 0.8$; *d* for $t_1/t_0 = 1.0$

5 show the curves of relation between ln (N/N_0) and τ for the diapositive and the reproduction plates with various t_1/t_0. This relation would be linear if Eq. (3) were correct.

Meikliar has shown that in the process of the relaxation of the photoconductivity in crystals of silver halide the following equation holds:

$$\frac{\Delta\sigma}{\Delta\sigma_0} = \frac{1}{(1 + at)^{\alpha}},$$

where $a \approx 10^3$ for thin monocrystals and $0.2 < \alpha < 0.5$. It is interesting to note that a similar law also governs the process of the regression of the centers of the latent image.

For this process the relation has the following form

$$\frac{N}{N_0} = \frac{1}{(1 + N_0 k\tau)^{\alpha}}. \tag{5}$$

The proof of the correctness of the Eq. (5) is found in the curve plotted for the values showing the relation between the reciprocal of the logarithmic derivative and τ. It should be linear since it appears from the Eq. (5) that

$$-\frac{1}{d\ln(N/N_0)/d_{\tau}} = \frac{1}{\alpha}\tau + \frac{1}{N_0 k\alpha}$$

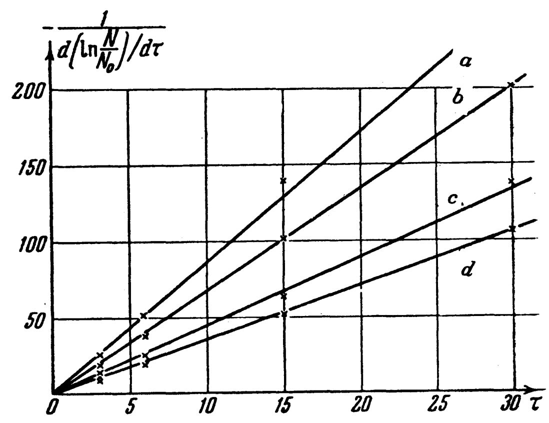

Fig. 6. The graph showing the relation between $-\frac{1}{d\ln(N/N_0)/d\tau}$ and τ for the diapositive plates. The line *a* for $t_1/t_0 = 0.4$; *b* for $t_1/t_0 = 0.6$; *c* for $t_1/t_0 = 0.8$; *d* for $t_1/t_0 = 1.0$

The results of such an examination are shown in Fig. 6 for the diapositive plates, in Fig. 7 for the reproduction plates, and in Fig. 8 for the Polish photographic paper "Photon".

The values lg H on the paper "Photon" were evaluated visually by comparing the changes of densities in the sensitogram produced after the regression had taken place with those of the sensitogram obtained immediately after the exposition.

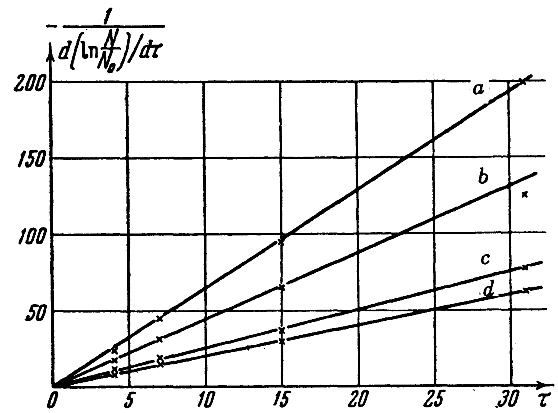

Fig. 7. The graph showing the relation between $\frac{1}{-d\ln(N/N_0)/d\tau}$ and τ for the reproduction plates. The line a for $t_1/t_0 = 0.4$; b for $t_1/t_0 = 0.6$; c for $t_1/t_0 = 0.8$; d for $t_1/t_0 = 1.0$

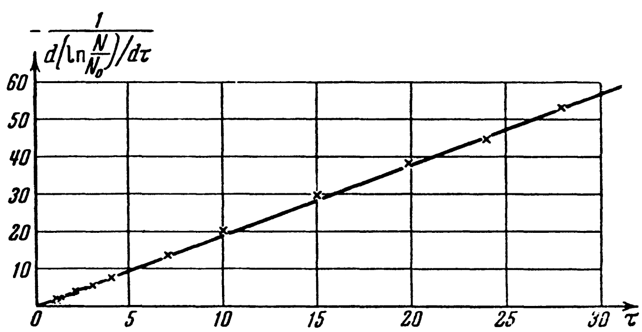

Fig. 8. The graph showing the relation between $\frac{1}{-d\ln(N/N_0)/d\tau}$ and τ for the photographic paper "Photon"

The resulting values α are found within the same limits as those taking place for the relaxation of the photo-conductivity. This is well illustrated by means of the following table.

Table

Values of α

t_1/t_0	Photomaterials		
	Diapositive Plates	Reproduction Plates	Photo Paper "Photon"
1.0	0.28	0.50	0.52
0.8	0.22	0.39	-
0.6	0.15	0.23 - 0.25	-
0.4	0.12	0.16	-

Since the value $N_0 k$ is great, the quantity $1/N_0 k\alpha$ must be very small. Hence the lines in Figs. 6, 7, and 8 pass practically through the origin of the coordinates, which means that the following relation is essentially correct:

$$N/N_0 = c\tau^{-\alpha},$$

where

$$c = 1/(N_0 k)^{\tau}.$$

From the resulting data one may deduce that the kinetics of the regression of the centers of the latent image is similar to the kinetics of the photoconductivity [5] and the luminescence [6]. From this it may also be deduced that the kinetics of the regression are determined by the electronic part of this process, which is bimolecular in its character.

This is in accordance with the data by Cherdyntsev [7] who found that bimolecular reaction of the type $(1/m) - (1/m_0) = \text{const.}\ t$ takes place in the thermal destruction of minute particles of silver preliminarily discharged through the photochemical process. Our conclusions are also in agreement with the results of the work by Hedges and Mitchell [8]. These authors have shown that under the action of light the crystals of silver bromide discharge the atoms of bromide. These atoms not only can enter into a combination with the photolithic silver but also destroy the silver particles with which the crystals were previously dusted.

The results of the experiments showing the in-

[5] P. V. Meikliar, J. Exper. Theoret. Phys. USSR 21, 42 (1951)

[6] S. I. Golub, Doklady Akad. Nauk SSSR 60, 1153 (1948), works of the State University of Odessa 3, 41 (1951)

[7] S. V. Cherdyntsev, J. of Phys. Chem. USSR 15, 419 (1941)

[8] J. M. Hedges and J. W. Mitchell, Phil. Mag. 44, 357 (1953)

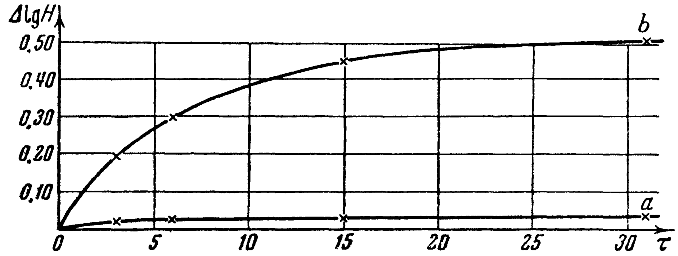

Fig. 9. The regression curve of the diapositive plates.
a - curve for the plate processed with 3% solution of borax.
b - same for the unprocessed plate.

crease of the regression in the atmosphere of oxygen, especially when it is filled with the vapor of water, and the decrease of the regression in the vacuum are often cited in support of the oxidation theory of the regression. It seems to us that these results are not yet sufficient to prove the oxidation theory. Any sharp change in the medium which surrounds the emulsion crystal is apt to affect the kinetics of the processes taking place on its surface irrespective of their mechanical nature.

Thus in the work by Bube [9] it has been shown that the presence of water vapor decreases considerably the time of the relaxation of the photo-

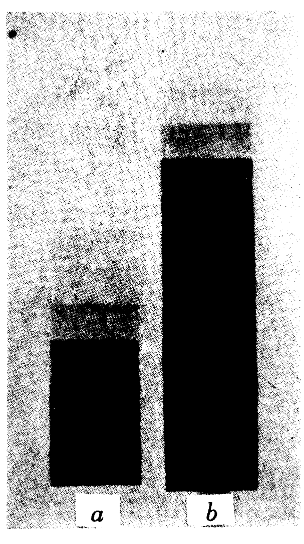

Fig. 10. The sensitograms produced on photo paper "Photon".
a- for the development carried out after a lapse of 6 days upon the exposure.
b- for the development carried out immediately after the exposure.

conductivity in the CdS crystal, also that the time of relaxation increases in the vacuum. In other words, the presence of water vapor increases the velocity of the recombination of perforated electrons and decreases it in the vacuum.

It is known[4] that the regression of the traces left by ionizing particles within plates with thick strata decreases when the plates are treated with borax. A similar effect has also been observed for the regression taking place in the ordinary plates. This is seen in Fig. 9, where the curve *b* relates to the regression in the unprocessed diapositive plates, and the curve *a* relates to the regression in the plates treated with borax.

In Fig. 10 are given two sensitograms, one produced on the paper "Photon" with the exposure made just before the development (*b*), and the other one for the regression which took place during 6 days of storage (*a*).

Similar sensitograms appear in Fig. 11 for the paper preliminarily treated with 3% solution of borax

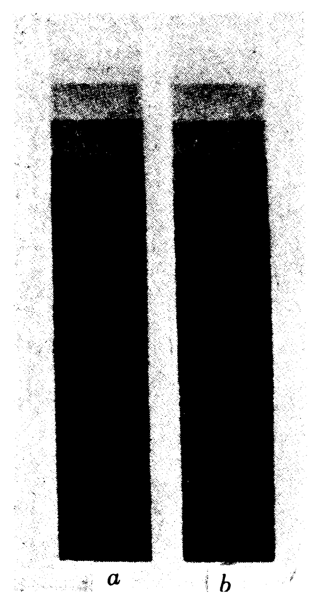

Fig. 11. The sensitograms produced on photo paper "Photon" treated with 3% solution of borax.
a- for the development carried out after a lapse of 6 days upon the exposure.
b- for the development carried out immediately after the exposure.

Translated by V. J. Doberly.

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[9] R. Bube, Phys. Rev. 83, 393 (1951) J. Chem. Phys. 21, 1409 (1953)

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