Acta Universitatis Carolinae. Mathematica et Physica

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Acta Universitatis Carolinae. Mathematica et Physica, Vol. 4 (1963), No. 2, 131--136

Persistent URL: `http://dml.cz/dmlcz/142159`

1968 ACTA UNIVERSITATIS CAROLINAE — MATHEMATICA ET PHYSICA NO. 2, PAG. 131—136

A CONTRIBUTION TO THE CONDUCTIVITY OF PHOTOGRAPHIC EMULSIONS

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INTRODUCTION

Attempts explaining the origin of the latent image in sensitive photographic layers often discuss the close conjunction of processes (electronic and ionic) present during the formation of the latent image with those concerning photoconductivity or luminescence in the same materials. It is therefore possible to presume that a mutual connection exists between the so-called photochemical sensitivity of the photographic layer on one hand and photoconductivity or luminescence on the other. This is so, because that part of the photoelectrons which will participate in the formation of the latent image [1] cannot take part in e. g. luminescence and at the same time will influence, depending on the sensitivity of the layer (i. e. depending on the number and energy levels of the active trapping centres for photoelectrons in silver halide crystals), the size and course of the growth of photoconductivity of a definite photographic layer. Similar questions were studied by Vacek [2] and lately analogical problems are studied by Gross [3].

This work studies the connection between the photochemical sensitivity and the course of the total conductivity (electronic and ionic) in the dark and under illumination for different photographic materials.

EXPERIMENTAL PART

The measurement of conductivity was made by a direct current method at room temperature. The illuminating apparatus, which was placed on Bouček's optical bench, consisted of a sensitometric lamp of defined spectral distribution, a condensing lens with a stop, a slit and convex lens. The sample holder was placed on the same bench and therefore the light from the optical system fell directly on the sample. Two nickeled electrodes were in contact with the sample and were connected by a coaxial cable to a direct current amplifier (of high input resistence) which in turn was connected to a galvanometer with an Ayrtone shunt. The light ray from the galvanometer was automatically registered by a kymograph and the course of the curve was controlled by observing the meter of the amplifier or by an oscilloscope. A diagram of the apparatus is shown in fig. 1.

Two types of photographic layers were used for the conductivity measurements: comercial light-sensitive material and laboratory prepared

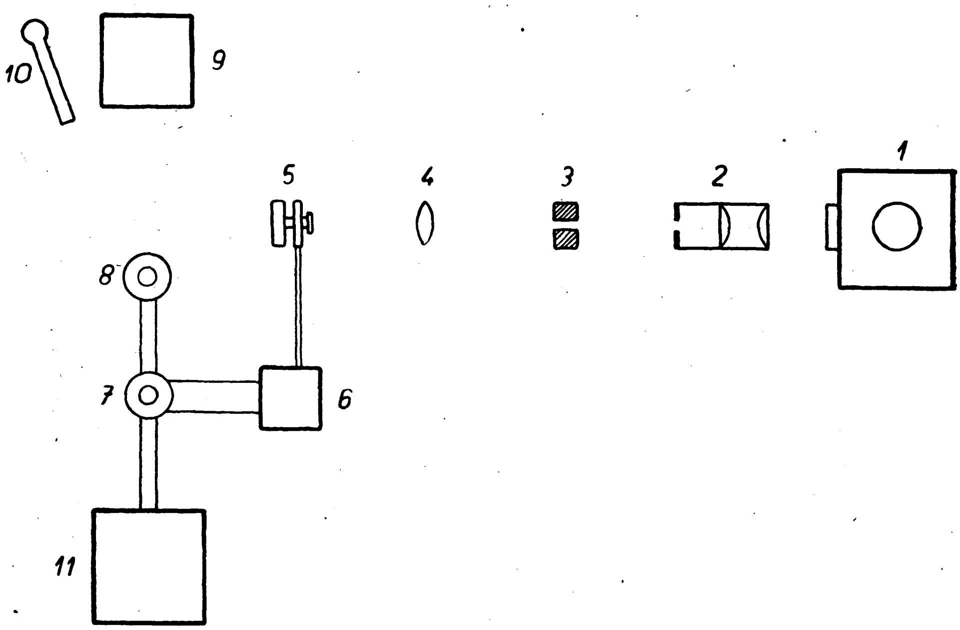

Fig. 1. 1. source of light on BOUČEK's bench; 2. condensor lens with a stop; 3. slit (Spindler & Hoyer); 4. convex lens; 5. sample holder; 6. DC amplifier Knick; 7. Ayrtone shunt (Metra); 8. galvanometer with a small time constant (Hartmann & Braun); 9. kymograph (Zličín); 10. projection lamp; 11. low speed oscilloscope OPD-250 (Tesla).

nuclear emulsions. All materials were prior to measurement kept at 58 % relative humidity.

The determination of the light sensitivity was made by exposure in a FSR_4 sensitometer and all the materials were developed in the same manner by a method used for the determination of sensitivity to the total radiation effect in nuclear emulsions [4].

RESULTS AND DISCUSSION OF MEASUREMENTS

Fig. 2 shows the characteric curves of these photographic layers for which Table 1 gives conductivity measurements results. The table only shows typical cases from a series of measurements. Fig. 3. shows an example of the registered curves.

From the measured curves we evaluated the ratio of the maximum values of conductivity in the dark (i_1) and at constant illumination (i_2). The sample was illuminated symetrically between the electrodes by the sensitometric lamp of 450 W from a distance of 0.79 m.

From the experimental procedure it is evident that the measured course of the curves includes the influence of small irreversible changes caused

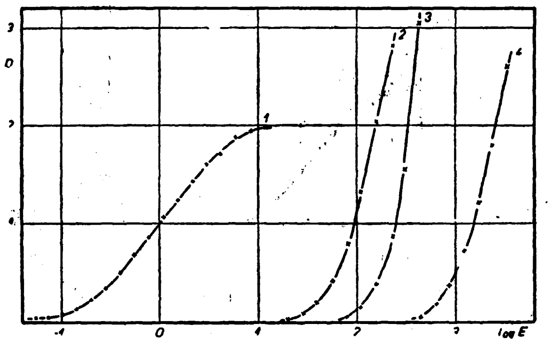

Fig. 2. Characteristic curves for different photographic materials. Curves: 1 — gradual-ortho Foma; 2 — Dia U Foma; 3 — nuclear emulsion sensibilised with gold; 4 — unsensibilised nuclear emulsion.

by electrolysis and space charge. All pairs of measurements were therefore made on separate samples. At the same time it is necessary to mention the fact that for the measured dependences these inaccuracies did not fundamentally influence the reproducibility of our results because the curves (i_1, i_2) are evaluated differentially.

It is necessary to note that all the nuclear emulsions have a small sensitivity to light. According to Kartuzanskiy [6], this fact can be attributed to the size and topography of sensitive centers in AgHal. crystals and to the so-called F-centers. Our opinion is that the experimental material necessary for a precise explanation of the effect is not yet sufficient. For the interpretation of our results, however, it follows that the nuclear and light sensitive results must be discussed separately. It was found that for each type of the used photographic material the found connection between the conductivity of the photographic layers and their sensitivity to light is analogous.

By comparing the values from Table 1 and the course of the characteristic curves in fig. 2 it is evident that for each type of photographic material the higher sensitivity corresponds to the higher value of the ratio between the total conductivity in the dark and under illumination. This result can be quite easily explained. The measured conductivity in the photographic layer at room temperature consists of electronic (or photoelectronic) and ionic (mainly intersticial silver ions) constituents. The higher the sensitivity

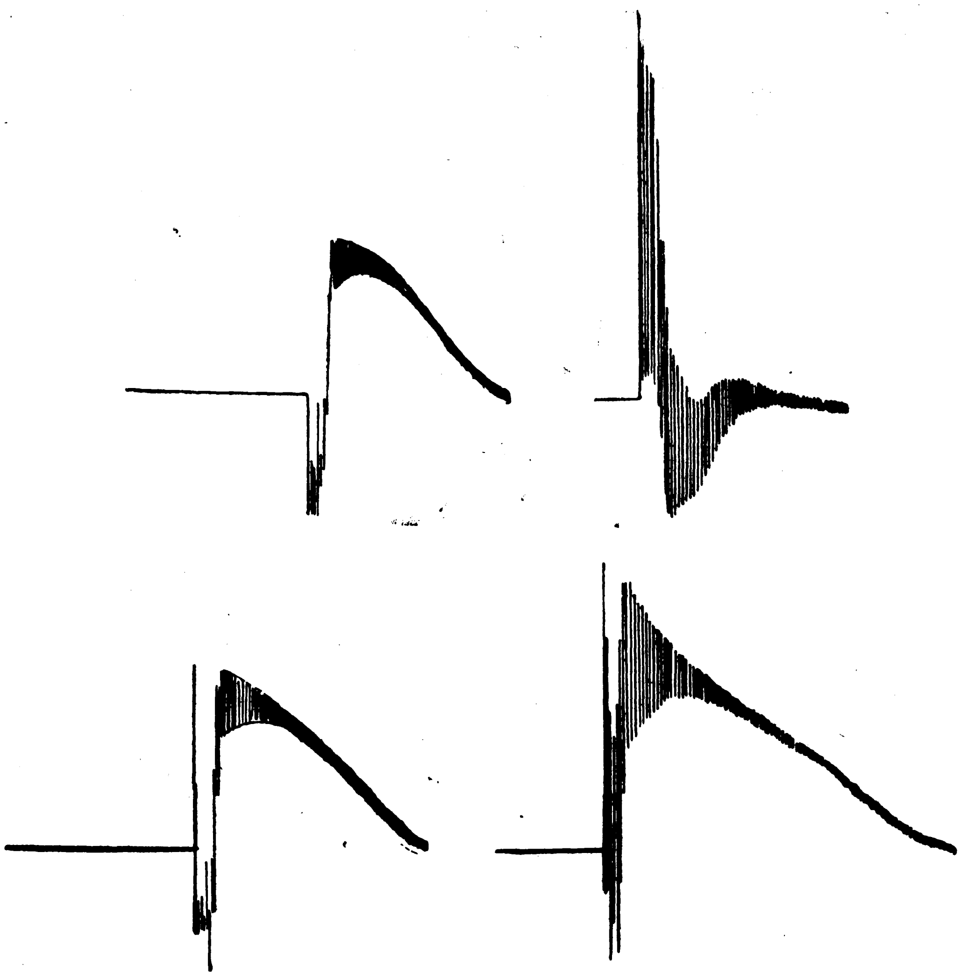

Fig. 3. Curves showing the rise in conductivity for photoemulsion Ortho-gradual (A) and AgCl single-crystal (B) in the dark (1) and under illumination (2).

of the photographic layer the higher the concentration of the deep trapping centers in silver halide crystals i. e. after illumination of the photographic layer most of the freed photoelectrons are trapped. The trapped photoelectrons on the trapping centers attract intersticial silver ions and neutralise them: $Ag_0^+ + e^- \rightarrow Ag_0$. Apart from that, part of the electrons are trapped on shallow trapping centers or may nonradiatively recombine with holes. The conductivity under illumination is lower in comparison to conductivity in the dark, for the number of Ag_0 ions which can take part in the conductivity is lowered for the above reasons.

In materials of low sensitivity, where the concentration of trapping centers is much lower, most of the photoelectrons are not trapped. This means that for a time they can take part in the conductivity (before they nonradiatively recombinate) and therefore the conductivity of the layer rises under illumination. That is why the ratio for these materials is less than one.

All these considerations confirm the measurements of conductivity made on pure AgCl single-crystals, where the concentration of trapping centres in comparison to the photographic layer is a minimum. That is why the ratio is smallest for these pure crystals as is shown in Table 1.

The conductivity measurement of a fogged photographic material ($D_0 > 3$) was also made. The result of the measurement is interesting because the ratio was less than one in all cases.

Table 1

Phot. material	i_1/i_2		Remarks
Light sensitive emulsion	Gradual-ortho Foma	6 6	17/10 DIN
	Dia U Foma	2.3	3° Sch
Nuclear emulsion	sensibilised	3	em. sens. with gold 0.4×10^{-4} M $AuCl_3$; $0,5 \times 10^{-2}$ M NaCNS for 1 mole of Ag; t_{II} = 5 hrs at 45 °C
Nuclear emulsion AgCl single-ctrystal	unsensibilised	$0,8_6$ $0,4_7$	t_{II} = 5 hrs at 45 °C crystals prepared according to 5

The study of the connection between conductivity and sensitivity of photographic layers is continued because these measurements could have practical applications. By ascertaining the correlation between the measured quantities it would be possible to use the measurement of conductivity as a fast control method in photographic industry.

The authors would like to thank Mr. J. Mokrejš for the construction of the sample holder, Mr. K. Hofmann for the measurement of the sensitometric lamp and Mr. F. Kundrát for reproducing the figures and graphs.

CONCLUSION

The analogous course of the photochemical sensitivity of light-sensitive and nuclear emulsions and their conductivity in the dark and under illumination was ascertained.

O VODIVOSTI FOTOGRAFICKÝCH EMULSÍ

Byl zjištěn analogický průběh mezi fotochemickou citlivostí světlocitlivých a jaderných emulsí a jejich vodivostí za tmy a při osvětlení.

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