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Research of the laser Weigert effect and laser solarization in short exposition region by laser light on the low-sensitive etched photoemulsion

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ABSTRACT

With the help of laser light λ = 10600 nm, the power P = 4,2 W, strength of electrical field in a beam of laser light E = 1,5·104 V/m and low exposition time (5 s) we got laser Weigert effect and laser solarization of the etched photoemulsion СП-1 with 6 units GOST sensitivity.

KEYWORDS

Weigert effect;
Chains of silver particles;
Laser solarization;
Latent image centres;
AgBr microcrystals.

INTRODUCTION

As it is known solarization of a photolayer is observed at the decreasing of photographic density D of an etched photolayer on white light exposition which is hundred times more than those giving negative images (more than 10 hours). The silver particles with the ability to development are responsible for solarization (latent image centres (LICs)). Nature of the solarization and normal Herschel effect is coagulative[1]. Herschel effect is solarization in the red light[2]. Decreasing of solarization is possible in 2 ways: 1) crushing of silver particles responsible for solarization with the increasing of their ability to development, and 2) creation new LICs with the ability to development in the region of solarization of a photolayer from silver of the coagulative centres after the exposition by the white light.

Solarization of a photolayer on the short exposition by the white light can also be got[3], if photolayer have been treated by aqua solution of sodium thiosulphate ($Na_2S_2O_3 \cdot 5H_2O$). It causes etching of AgBr microcrystals.

AgBr microcrystals of photoemulsion has symmetry m3m and cubic etching pits[4]. In the etching process there is the strength of the electric field $E \approx 10^4$ V/m[5] on the flat sides of etching pits. Ions of silver can fall to etching pits and create LICs there via electrons attachment. With the help of electron-microscopic method was determined that particles of silver were created in the etching pits.

Now anywhere in this article we are using photoemulsion СП-1 with the 6 units GOST sensitivity which was etched (before exposition) by aqua solution of sodium thiosulphate ($Na_2S_2O_3 \cdot 5H_2O$) with different concentrations (the concentration 100% is 0,25 kg of sodium thiosulphate per litre of water). Also the photoemulsion was illuminated by infrared (IR) laser beam with the following characteristics: generation regime of laser polarized light is continuous (gas laser with compound $CO_2 + N_2 + He$), λ = 10600 nm and power

P = 4,2 W, diameter of the laser beam d = (3± 0,1)·10^{-3} m, strength of electrical field in a beam of laser light E = 1,5·10^4 V/m.

The amount of solarization depends on the concentration of aqua solution of sodium thiosulphate (Figure 1), the duration of etching time (Figure 2), and the duration of exposition by the white light of photoemulsion (Figure 3).

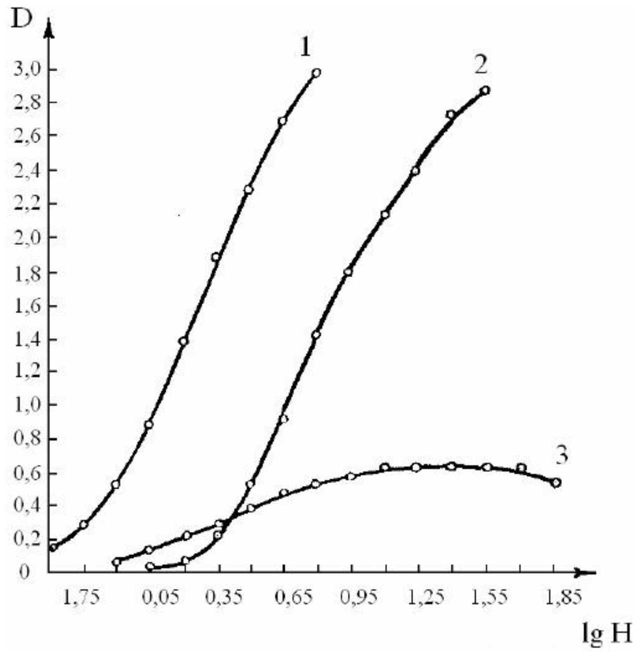

Figure 1 : Characteristic curves for photoemulsion CП-1. Curve 1 - without etching, 2 - with etching by aqua solution of sodium thiosulphate with the concentration 9% of $Na_2S_2O_3$·$5H_2O$ during 60 s, 3 - with etching by aqua solution of sodium thiosulphate with the concentration 12% of $Na_2S_2O_3$·$5H_2O$ during 720 s (solarization). The duration of exposition was 1s for all these curves by white light in the sensitometer ΦCP-41.

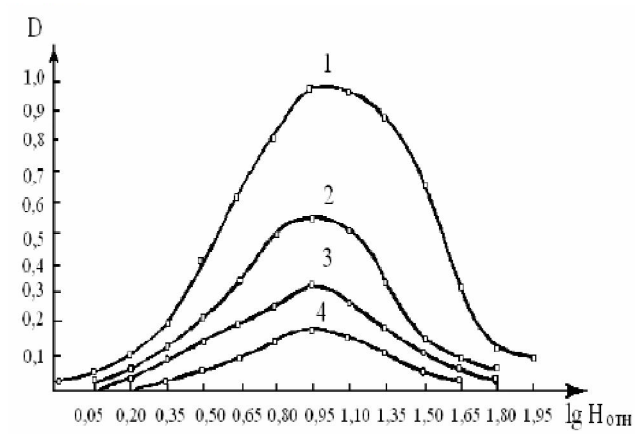

Figure 2 : Characteristic curves for solarization of photoemulsion CPП-1 etched by aqua solution of sodium thiosulphate with the concentration 50 % of $Na_2S_2O_3$·$5H_2O$. The duration of exposition was 1s for all these curves by white light in the sensitometer ΦCP-41. Curve 1 – etching during 60 s, curve 2 - etching during 120 s, curve 3 - etching during 180 s, curve 4 - etching during 240 s.

It was necessary to get laser solarization for short time by laser light of the etched photoemulsion CП-1.

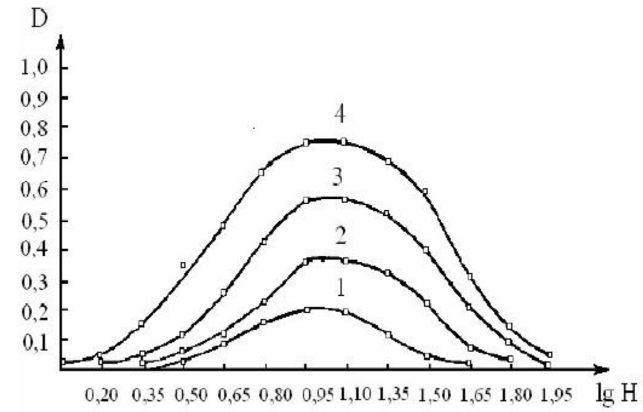

Figure 3 : Characteristic curves for solarization of photoemulsion CП-1 etched by aqua solution of sodium thiosulphate with the concentration 50 % of $Na_2S_2O_3$·$5H_2O$ for all these curves during 240 s. Curves 1, 2, 3, 4 are got for solarization on short expositions by white light (1 s (curve 1), 2 s (curve 2), 3 s (curve 3), 4 s (curve 4)).

METHODS

Technique of laser solarization obtaining

To get laser solarization we turned to the preparatory etching of photoemulsion in aqua solution of sodium thiosulphate with the concentration 50 % of Na_2S2O_3·$5H_2O$, to the exposition of photoemulsion by IR laser light, and with the help of the electron-microscopic method. To describe the processes taking place during laser solarization we used the computer modeling technique.

Technique of etching and changing of photographic parameters of photoemulsion

Photographic plates CП-1 were plunged into aqua solution of sodium thiosulphate with the concentration 50 % of $Na_2S_2O_3$·$5H_2O$ at T = 293 ± 0,1 K, and then flashed in the sensitometer ΦCP- 41[6]. With the help of the sensitometer ΦCP - 41 in a standard way it is possible to get a sensitogram, and after development in the K. Chibisov's developer at the developing temperature 293 ± 0,1 K with the help of a microphotometer МФ-2[7] it is possible to measure optical density D of every region of a sensitogram, and to get characteristic curves in coordinates D and lg(H).

Technique of illumination by laser light

In darkness laser beam is directed perpendicular to vertically located etched photographic plate (PP) СП-1. PP was kept by special device in the plate holder with the open screen, and the platform was moving with the steady speed $1{,}6\cdot10^{-4}$ m/s (distance equal to the diameter of a laser beam was surpassed for 18 s). Power of laser beam was measured by the device ИМО - 2.

Technique of electron-microscopic research

The transmission electron microscope (TEM) BS-613 of TESLA Co (Czechoslovakia) with resolution not worse than 4,5 Å was used. The collodion replicas with AgBr microcrystals of the etched PP were prepared. Illumination was changed into laser light during 2 s without development. Collodion was dissolved in 1 % amyl acetate solution. To prevent replicas heating and ripping up by beam of electrons they were chilled in the electronic microscope with liquid nitrogen before and during photographing. Those replicas did not tone with carbon. Photographic plates out of the microscope were developed with the help of K. Chibisov's developer at the developing temperature $293 \pm 0{,}1$ K, and fixed in a fixage. With the help of the white circle on the PP at the location of the laser beam the diameter of the laser beam $d = (3 \pm 0{,}1)\cdot10^{-3}$ m was measured. In figure 4 elecrton-microscopic images a), b), c) of collodion replicas of AgBr microcrystal are presented. With the help of them the size of LICs during solarization is possible to determine.

Computer modeling technique

The computer model[8,9] (Borland Pascal 7.0 in terms of programming) was used for analysis of laser solarization. The initial data for solution of differential equations were the following: Ag ionic concentration $n_i = 0$ m^{-3}, Ag atom concentration $n_a = 10^{24}$ m^{-3}, Br atom concentration (holes) $n_h = 0$ m^{-3}, minimal radius of a silver clot $R = 1{,}44\cdot10^{-10}$ m. The AgBr microcrystals is wide-gap semiconducting microcrystals with n-type conductivity. After etching these microcrystals has large concentration of defects. This leads to the appearance of additional levels and narrowing of the forbidden band. Also, electron emission occurs from particles Ag. The reason for the emission of electrons from the particles Ag is the heating of the electron gas silver particles. The number of quanta of laser with $\lambda = 10600$ nm appeared within a 1 s was counted according to the formula

$$N = \frac{\eta\cdot P\cdot\lambda}{h\cdot c} \qquad (1)$$

where $\eta = 0{,}5$ is the efficiency of laser beam, hh = $6{,}63\cdot10^{-34}$ J·s is Plancconstant, $c = 3{,}00\cdot10^{8}$ m/s is the speed of light in vacuum, P = 4,2 W is the power of laser beam. To make calculations we used microcrystal sizes: 0,5 μm × 0,5 μm × 0,1 μm. Out of proportion due to the cross section area of the beam ($d = 3\cdot10^{-3}$ m) we found out the number of quanta fell down to the microcrystal $N \approx 112\cdot10^{18}$ s^{61}. The number of ions σ_V which are formed for 1 s by the heating action of IR light in microcrystal was equal $2\cdot10^{32}$ for this computer model.

EXPERIMENTAL RESULTS AND DISCUSSION

IR light can create a latent image on the photoemulsion layers[10]. Strength of electrical field in a beam of laser light in vacuum was counted according to the formula[11]:

$$E = \sqrt{\frac{4P}{\pi\cdot d^2\cdot\varepsilon_0\cdot c}} \qquad (2)$$

where P is an optic power of laser, d is a diameter of the laser beam, ε_0 is dielectric constant, c is light speed, $\pi = 3{,}14$. Values for substitution P = 4,2 W, $d = 3\cdot10^{-3}$ m, $\pi = 3{,}14$, $\varepsilon_0 = 8{,}85\cdot10^{-12}$ C/Vm, $c = 3\cdot10^{8}$ m/s gives the value $E = 1{,}5\cdot10^{4}$ V/m. Due to electron-microscopic method sizes of the developed LICs and the particle responsible for solarization[12] were established. Let's count the average number of of atoms in LICs responsible for solarization. We will consider a latent image centre to be in a sphere form with the diameter 2R. While counting the volume of a latent image centre, using the dimensions of it on the electron-microscopic image on the PP and magnification of the electron microscope and be aware of the volume of the Ag atom in a crystal ($V_{Ag} = 17{,}06$ Å^3[13]), we find out the number of atoms in LICs. Calculations shows that the appearance of LICs with dimensions 15-20 ú fulfills 100-250

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atoms on the average; and silver particles on the solarization with the size ≈ 100 Å fulfills ≈ $3\cdot10^5$ atoms. The received values corresponds data[6] about the opinion that the latent image centre is a crystal of a phase of metallic silver consisting of a few tens or hundreds Ag-atoms.

In Figure 4 a) b), c) there are electron–microscopic images of AgBr microcrystal. In figure 6 there are the dependence of the volume of silver particles, of Ag ions concentration, Br atoms and Ag atoms concentration on the time of IR illumination. Dependence (Figure 6) is got via computer modeling method accustomed for solarization conditions.

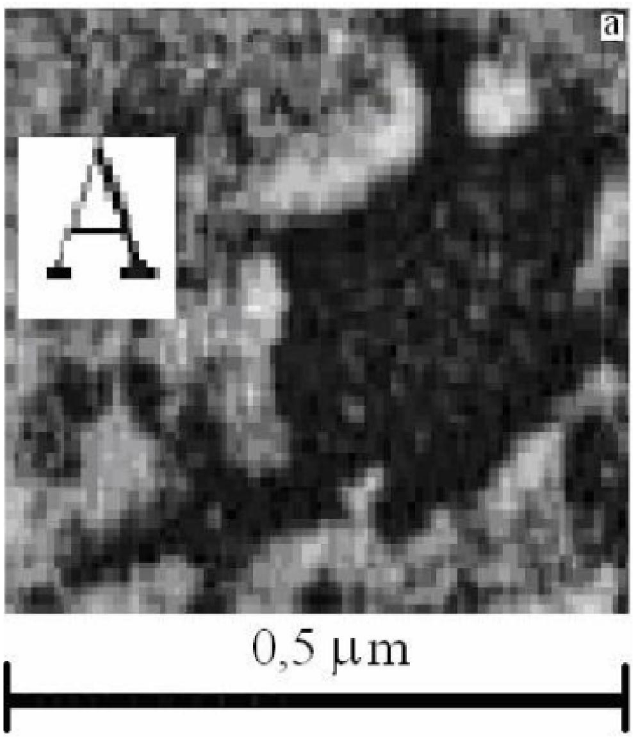

Figure 4 (a) : Electron-microscopic image of replica of AgBr microcrystal of photoemulsion CП-1 after having been etched of AgBr microcrystals by aqua solution of sodium thiosulphate with the concentration 50 % of $Na_2S_2O_3\cdot5H_2O$ (120 s), and then exposed by the white light (2 s).

Figure 4 a) shows the creation of silver particles having sizes ≈ 2000 Å (particle A) on the surface of AgBr microcrystal.

Figure 4 b) shows chaining of silver particles with the diameter ≈ 2000 Å where particles in chains has close fit to each other. The chain formation of spherical silver particles in the process of illumination by polarized light is known as Weigert effect[14]. The creation of chains probably is conditioned by dipole interaction of Ag particles in the chain. Under the action of laser with λ = 10600 nm, P = 4,2 W the emission of electrons out of Ag particles on the surface of AgBr microcrystal takes place. The reason of that emission is nonequilibrium heating of electron gas of Ag particles[17]. Laser beam energy is absorbed by the whole ensemble of electrons of each Ag particle[17]. On the AgBr microcrystal (Figure 4 c) (place B) it is obvious to see the large centres of solarization created on the etched surface of AgBr microcrystal.

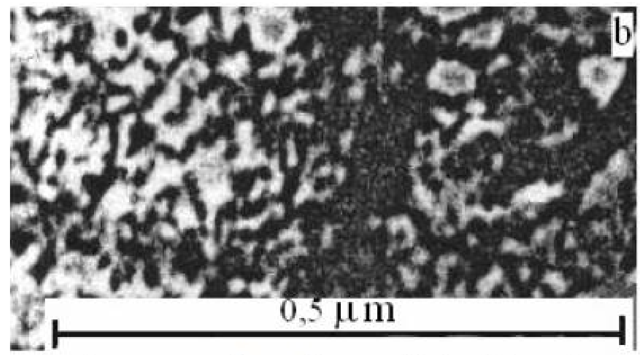

Figure 4 (b) : Electron-microscopic image of replica of AgBr microcrystal of photoemulsion CП-1 after having been etched of AgBr microcrystals by aqua solution of sodium thiosulphate with the concentration 50 % of $Na_2S_2O_3\cdot5H_2O$ (120 s), and then exposed by laser polarized light with λ = 10600 nm, P = 4,2 W (1 s). In the image there is a part of the AgBr microcrystal surface with the chains of silver particles.

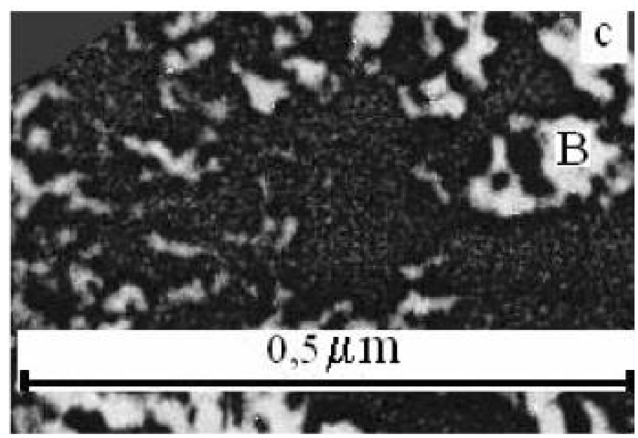

Figure 4 (c) : Electron-microscopic image of replica of AgBr microcrystal CП-1 after having been etched of AgBr microcrystals by aqua solution of sodium thiosulphate with the concentration 50 % of $Na_2S_2O_3\cdot5H_2O$ (120 s), and then exposed during 5 s by laser light.

Figure 4 c) shows (place B) that oblong particles with the size ≈ 952,4 Å were made out of the silver particles chain though they had been exposed by white light. The creation of large centres of solarization is possible due to such mechanism. Actions of electric field of the polarize laser light leads to the division of charge of silver particles and to the appearance electrical dipole moments there[18]. In such a case silver particles responsible for solarization are created. Laser Weigert effect passes into laser solarization. Thus, laser light with λ = 10600 nm, power 4,2 W, and time 5 s can create solarization of AgBr microcrystals.

In the works[14-16] it was indicated that the character of Weigert effect lies on the united into the chain silver particles. Weigert effect is conditioned by the creation of chains and dipole interaction of silver particles in a chain.

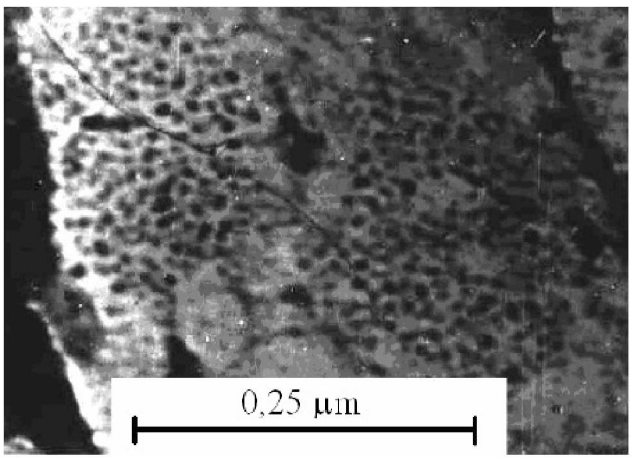

Figure 5 : Electron-microscopic image of replica of AgBr microcrystal of photoemulsion CП-1 exposed by laser light with λ = 440 nm, P = 10 mW during 1/60 s (Weigert effect)

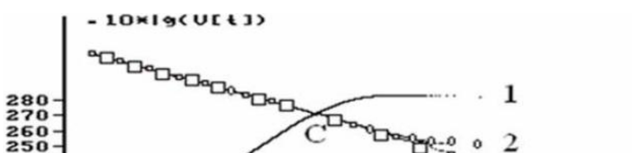

Figure 6 : Time change in the process of laser solarization of silver clots V(t) (curve 1), Ag atoms concentration n_a(t) (curve 2), Ag ions concentration n_i(t), and Br atoms concentration n_h(t) (curve 3).

Result of computer modeling of laser solarization is shown in Figure 6. Curves 1, 2, 3 are crossed in one point C. Maximal volume of a silver clot is $\approx 8\cdot10^{-19}$ m^3 (R $\approx 5{,}76\cdot10^{-7}$ m), minimal volume of a silver clot is $\approx 9\cdot10^{-22}$ m^3 (R $\approx 5{,}99\cdot10^{-8}$ m). The obtained sizes of silver particles correspond to the region of solarization on the characteristic curve. The peculiarity of curves for laser solarization with λ = 10600 nm is juxtaposition of Ag ions concentration, Ag atoms concentration, and Br atoms concentration curves.

CONCLUSIONS

Continuous laser polarized light with λ = 10600 nm, P = 4,2 W effecting AgBr microcrystals of the photoemulsion CП-1 with the 6 units GOST sensitivity etched by aqua solution of sodium thiosulphate with the concentration 50 % of $Na_2S_2O_3\cdot5H_2O$ during 120 s is able to

(1) make Weigert effect during 1 s; that effect simplifies the process of laser solarization;

(2) make laser solarization during 5 s with T = 293 ± 0,1 K.

Laser solarization was got within a short time period of exposition (5 s).

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