THE SPECTRAL DISTRIBUTION OF THE PHOTOSENSITIVITY OF THE TWO-COMPONENT ELECTROPHOTOGRAPHICAL LAYERS OF TRIGONAL $Se/CdInGaS_4$

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The two-component electrophotographical (EP) layers of the trigonal $Se/CdInGaS_4$ in connecting with optimal EP parameters (U_H=300V, $\tau_{1/2}$=40s, $S_{int..}$=0,13$Lk^{-1}\cdot s^{-1}$) at the relation 1:1 of components and with spectral region of photosensitivity till $\lambda \geq$800nm are obtained.

Earlier the electrophotographical (EP) layers on the base of the trigonal Se and the compound $CdInGaS_4$ in the connecting [1-3] were investigated by us. The measures of the main electrophotographical parameters show that layers from the trigonal Se have high light sensitivity (0.6$Lk^{-1}\cdot s^{-1}$ in the visible region of the spectrum), but they have the low initial potential the layers from the trigonal Se in the connecting charge positively till the surface potential ≤250V, have the high velocity of dark slump, the half-slump time ~35s.The small value of the initial potential of the layers from the trigonal Se is caused by the respectly low specific resistance of the photosemiconductor (10^7Ohm·cm). The EP layers on the base Cd $InGaS_4$ in the connecting have the low light sensitivity (0.003$Lk^{-1}\cdot s^{-1}$), but they charge till the initial potential U_h=1000V.

Taking into consideration above mentioned, the obtaining of the two-component EP layers, which will be combine the high light sensitivity of layers on the Se base and the big initial potential of the layers from $CdInGaS_4$ is very interesting.

The used by us the compound $CdInGaS_4$ had the specific resistance $\rho \approx 10^{10}$Ohm·cm in the darkness, the ρ decrease on 3 points was observed at the lightening by the white light (200 Lk).

The trigonal Se was obtained from the initial material by the mark Osch 17-4 by the preliminary thermotreatment in the quartz ampoules ($p<10^{-4}$mmHg) at 700°C during 3 hours, the quick cooling of the melt firstly till 250°C, later in the running water and crystallization at 210°C during 40 hours. The specific resistance of the trigonal Se, obtained by the such manner in the darkness was $\approx 10^7$Ohm·cm and it decreased on the 3 points at the lightening by the white light (200 Lk).

The layers of the 3 types were obtained by the method of the dispergation in the connecting: substrate –$CdInGaS_4$ - trigonal Se(I); substrate - trigonal Se - $CdInGaS_4$ (II); substrate - the mixture of trigonal Se and $CdInGaS_4$ at the different rates of the components (III).

The layers of I type were obtained by the following manner. The substrate from the aluminum foil by the thickness 150mkm was skimmed, poisoned and conserved. The layer of emitted in the spherical mill $CdInGaS_4$ in the connecting from the polyvinylbutyral, dissolved in the ethyl alcohol, by the thickness 15-20mkm, was carried on the substrate by the method of swimming roller. The middle size of the semiconductor particles was 15mkm. The trigonal Se in the connecting by the thickness 5-10mkm after drying on in the usual conditions during one hour crushed by the such manner was carried on the first layer.

The layers of II type were obtained by this method, but in the beginning the substrate was covered by the layer from the tetragonal Se in the connecting (20-30mkm), later the $CdInGaS_4$ on the first layer was carried on the first layer in the connecting by the thickness 5-10mkm.

The layers of III type were obtained by the carrying on the ready substrate of the mixture of two semiconductors in the connecting by the thickness 25-30mkm. Moreover $CdInGaS_4$ and the trigonal Se firstly were crushed till the middle size of particles 15mkm differently, later the joint crushing of the components in the different weight rate was carried out in the spherical mill with the addition of the connecting and the obtained dispergant was carried on the substrate. All layers were drying on the usual conditions at the room temperature.

The charging of the layers was carried out in the corona discharge (+7kV). The measurement of the main EP parameters was carried out on the electrometric installation with the oscillating electrode on the surface layer [4]. The light characteristics of the EP layers were measured by the exposuring through photoshutter with the use of the incandescent lamp and neutral photofilters. The illumination intensity was 125Lk, the exposuring time was variated by the photoshutter. .

The spectral distributing of the photosensitivity (S_λ) of the EP layers was defined in the interval λ=400÷900 nm with the use of the monochrometer of the spectrophotometer VSU2-P. The source of the lightening was graduated by the radiated compensated thermoelement PTH - 30.

The integral light sensitivity of the EP layers is defined by the velocity of slump of the potential at the lightening. The integral light sensitivity is characterized by the exposuring time t (in s) in the case of the constant illumination intensity L (in Lk), during of which the surface potential decreases in two times:

$$S = \left(\frac{1}{L \cdot t}\right)_{\frac{\Delta U}{U}} = \frac{1}{2} \quad , \qquad Lk^{-1}\cdot c^{-1}$$

(1)

The defined photosensitivity is called integral one.

The illumination intensity at the defining of the spectral photosensity of the EP layers is measured in the energetic unit (Vt/m^2) or number of the incident quantum on the unit area of the surface layer in the time unit:

$$S_{\lambda} = \left(\frac{1}{L_{\lambda} \cdot t}\right)_{\frac{\Delta U}{U}} = \frac{1}{2}, \text{ cm}^2\cdot\text{Joule}^{-1} \quad (2)$$

The parameters of the EP layers of I type seemed in the following manner: the initial potential U_H was 180 and 870 V of the makeup and subjected to the annealing at 160°C during 1 hour, accordingly; dark half-slump time $\tau_{1/2}$ was 4 and 15s, the integral sensitivity S_{int}, calculated by (1), till the annealing was 0.04, after 0.08 $Lk^{-1}\cdot s^{-1}$, the residual potential 20 and 60V, correspondingly.

The high velocity of the dark relaxation of the surface potential is observed on the initial area of the slump curve, as much as measured just after charging U_H=870V, later 5s U_H=600V. This reflects on the dark half-slump time correspondingly. Thus, measured just after charging $\tau_{1/2}$=15s, later 5s is equal 25s.

The measurements show that layers of II type have U_H, which is equal to 225 and 700V, but $\tau_{1/2}$ =5 and 20s till and after annealing at 160°C (1 hour). The light sensitivity of these layers is smaller, than the layers of I type have and it is equal 0,032 and 0,027 $Lk^{-1}\cdot s^{-1}$ till and after annealing. Thus the some slump of the integral light sensitivity is observed with the annealing, and the increase is observed in the photoreceptors with the surface layer of their trigonal Se in the connecting (I type).

The light sensitivity of the one-layer photoreceptors from $CdInGaS_4$ in the connecting with the annealing decreases, but the light sensitivity of the trigonal Se layers in the connecting increases. This explains the resolving of the defects in the particles of the trigonal Se during annealing, as Se has the low fusing point, and the annealing at 160°C can provide the given process. In the case of $CdInGaS_4$, having the high fusing point (950°C), the annealing at 160°C can't change the structure of the particles mainly.

The investigations of the photoreceptors of I and II types show that the dominating role in the forming of the EP parameters play the outside sublayer, accessible to the light.

The parameters of the layers of III type depend on the rate of the components and temperature of the following annealing significantly. Thus, the initial potential and the time of its dark half-slump of the layers with the different rate $CdInGaS_4$/Se increase with the annealing, achieving maximal value at $T_{an}\approx$160-170°C. U_H and $\tau_{1/2}$ decrease with the following growth T_{anl},. The integral light intensity S_{int} of these layers increases strongly with the growth T_{anl} (fig.1), saturating at $T_{an}\geq$180°C.

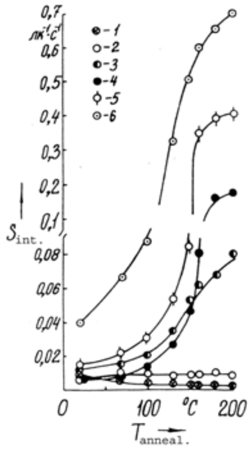

Fig.1. The dependence S_{int} of the layers of III type on T_{an} at the different content of the trigonal Se (1- 0; 2- 10; 3- 30; 4- 50; 5- 75; 6- 100% Se).

The dependences of the initial potential (U_H), half-slump time ($\tau_{1/2}$), integral light sensitivity (S_{int}) and the residual potential (U_{res}) from the content of trigonal Se in the layers of III type after annealing at 170°C(1 h) are presented on the fig 2, 3. It is seen, that the monotone change of all EP parameters is observed. The initial potential and the half slump time decrease with the growth of content of the trigonal Se in the layer (fig.2). Moreover the essential increase of the integral light sensitivity is observed with the growth of Se content (from 0.003 $Lk^{-1}\cdot c^{-1}$ for the layers from $CdInGaS_4$ till 0.6 $Lk^{-1}\cdot c^{-1}$ for the layers from the trigonal Se). At the same time the residual potential decreases from 300 till 10V. The analysis of the dependence of the parameters of the EP layers from the trigonal Se content allows to establish that the most optimal EP parameters have the layers with the rate 1:1.

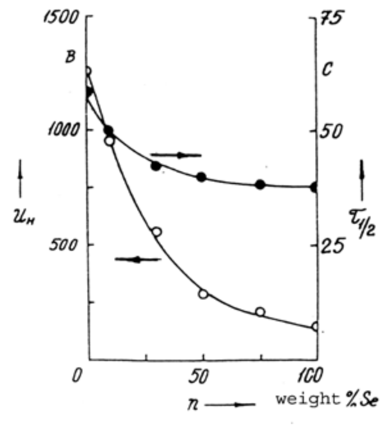

Fig.2. The dependence U_H and $\tau_{1/2}$ of the layers of III type from the content of the trigonal Se(T_{anl}=170°C, 1h).

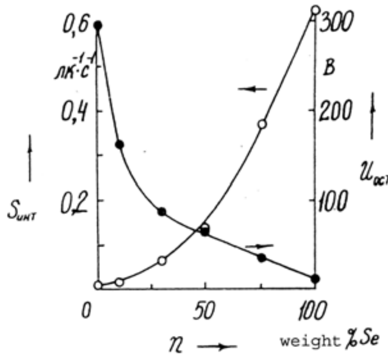

Fig.3. The dependence S_{int} and U_{res} of the layers of III type on the content of the trigonal Se (T_{an}=170°C, 1h)

The results of the measurements S_λ, calculated by the formula (2) are given on the fig.4. It is seen, that S_λ of the layers from the trigonal Se is more big than S_λ layers from $CdInGaS_4$ in the region λ=400÷900 nm (in 4÷2 times in dependence on λ). The photosensitivity of the two component layers of the trigonal Se/$CdInGaS_4$ (at the rate 1:1) in the given interval λ is smaller, than for the layers from the trigonal Se have, but the significantly bigger, than for layers from $CdInGaS_4$ have. However, the interesting peculiarity is observed: the photosensitivity of two-component layers is higher in region λ>650 nm, i.e. S_λ goes in the long-wave region of the spectrum.

In the process of the unit dispergation $CdInGaS_4$ and the trigonal Se the crushing of the both components was carried out and it is possible the enrichment of the surface of the separate scorns of the more solid $CdInGaS_4$ by Se. The last one leads to the sensibilization of the $CdInGaS_4$ photosensitivity during the annealing and to the increase of the light sensitivity of the EP layers. Moreover the crystals of the both semiconductors, rounded by the connecting substance lay on the substrate statistically uniformly with the alternation of the particles of that or another semiconductors at the carrying of the layer. The two electrographical layers form, the one in the matrix of the another, i.e. the two-layer photoreceptor is formed as a fact. Each of the separate layers carriers in the deposit in the parameters of such system.

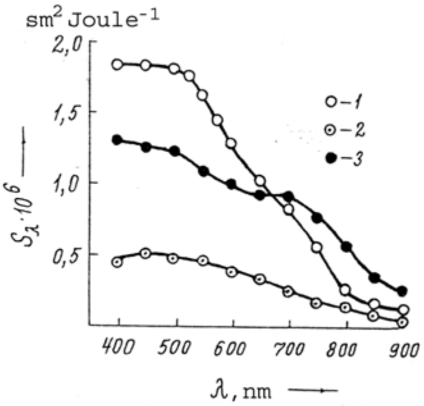

Fig.4. The spectral dependence S_λ of the layers on the base: the pure trigonal Se(1), pure $CdInGaS_4$ (2) and mixture of the trigonal Se/ $CdInGaS_4$ at the components' rate 1:1 ($T_{an.}$=170°C, 1h).

The above mentioned, we notice, that the two-component photoreceptors of the trigonal Se/ $CdInGaS_4$ in the connecting with the optimal EP parameters (U_H=300V, $\tau_{1/2}$=40s, $S_{int.}$=0.13 $Lk^{-1}\cdot c^{-1}$) at the rate of the components 1:1, the photosensitivity of which is till ≥800 nm are obtained.

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TRİQONAL Se/$CdInGaS_4$ İKİKOMPONENTLİ ELEKTROFOTOQRAFİK LAYLARIN FOTOHƏSSASLIĞININ SPEKTRAL PAYLANMASI

Optimal elektrofotoqrafik (EF) parametrlərə (U_i= 300 B, $\tau_{1/2}$=40 s, S_{int}=0,13 Lk-1(s-1) və λ≥800 nm-ə qədər spektral fotohəssaslığa malik olan, əlaqələndiricidə komponentlərin 1:1 nisbətində triqonal Se/$CdInGaS_4$ ikikomponetli EF laylar alınmışdır.

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СПЕКТРАЛЬНОЕ РАСПРЕДЕЛЕНИЕ ФОТОЧУВСТВИТЕЛЬНОСТИ ДВУХКОМПОНЕНТНЫХ ЭЛЕКТРОФОТОГРАФИЧЕСКИХ СЛОЕВ ТРИГОНАЛЬНОГО Se/$CdInGaS_4$

Получены двухкомпонентные электрофотографические слои тригонального Se/$CdInGaS_4$ в связующем с оптимальными ЭФ параметрами (U_H=300 В, $\tau_{1/2}$=40с, $S_{инт.}$=0,13$Лк^{-1}(с^{-1})$ при соотношении компонент 1:1 и со спектральной областью фоточувствительности до λ≥800 нм.

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