PHOTOSENSITIVITY FEATURES OF ELECTROPHOTOGRAPHIC LAYERS OF $CdInGaS_4$

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The quantum yield of $CdInGaS_4$ electrographical layrers without Au impurity and with it in region (300 – 1000nm) is investigated, as result of which the photosensitivity and quantum yield in spectrum visible part increase.

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The compounds of $A^{II}B^{VI}$, $A^{II}B_2^{III}C_4^{VI}$ [4-7] type and others from which $C_dI_nG_aS_4$ is considered in the present work in electrophotography (EPh) along with chalcogenide glasses [1–3]. Their monocrystalline samples are grown by us by gas-transport method. The have p-type conduction with E_g= 2,56 *eV*. At room temperature they have dark resistivity 10^{10} Om·см and relative photosensitivity $\geq 10^5$ at 10^3lux. The photosensitivity increases with Au impurity: $\geq 5\cdot10^6$.

The maximum of intrinsic photosensitivity is at 460nm on curves of photocurrent spectral distribution and additional maximum at Au impurity appears at 590nm. The absorption edge corresponds to 470 nm.

The investigation of absolute quantum yield of internal photoeffect of EPh layers on $CdInGaS_4$ base in spectrum region (300 –1000nm).

The measurement of quantum yield in the substances with low mobility is carried out by the one of two methods: method of transient photoconduction and EPh method. The one of the main advantages of EPh method is the posibility of high field formation (of order 10^6V·cm^{-1}) whereas the samples with metallic electrodes begin to decade at fields $1{,}5\cdot10^5$V·cm^{-1} and lower than this value.

The ion contact forms at measurement in EPh mode on layer surface situated on conducting substrate. The investigation task in layers with electric charge marked on their surface is unweighted because of the strong electric field presence the discharge photocurrent achieves the saturation value and this fact allows us to easily define the quantum output of internal photoeffect.

The penetration depth of surface charge field marked on the semiconductor layer with low conductivity can be equal to significant part of layer thickness and even whole layer thickness. In the case of field penetration to the whole layer thickness the free carriers are eliminated from the layer and the charge for the surface charge compensation accumulates in the substrate. In this case the layer behavior is well described by the model of double electric layer of constant thickness (plane capacitor). Analogically this layer can be considered in the case of incomplete penetration of surface charge field introducing the thickness formed at electrification of barrier layer (effective thickness) instead of the geometric one. We can easily ascertain calculating the capacitance of formed barrier layer $C = \frac{d\delta}{d|v|}$, where $\delta=\delta(x)$ is space charge density, $V=V(x)$ is layer potential. The potential distribution as charge functions is given by Poison equation which has the form in one- *D* case:

$$\frac{d^2V}{dx^2} = \frac{4\pi\delta}{E} \qquad (1)$$

where E is dielectric constant. Taking into consideration that electric field is equal to zero out of the barrier layer and on the its boundaries $\frac{dV}{dx}\Big|_{x=0} = 0$, $\frac{dV}{dx}\Big|_{x=x_1} = 0$, and integrating (1) taking into consideration these boundary conditions we obtain $C = \frac{E}{4\pi d_{ef}}$ if one consider that volume charge density of barrier layer is defined by only immobile charges. The last expression is analogous to the expression for the capacity of plane capacitor.

If we consider EPh layer as the homogeneous semiconductor having the strongly defined conduction and valence bands, then the considerable displacement of free carriers on whole layer thickness by the surface charge field leads to the band bend which distributes on whole layer thickness and forms the potential barrier between surface and screening charges. The barrier appearance plays the important role on layer dark characteristics increasing on 2-3 orders the layer resistance. The surface charge sign influences on potential relaxation time and the layer thickness efficiency, i.e. on value of limiting potential. However, the photocarriers don't overcome this barrier, as the photoinjection of electron-hole pairs takes place inside the barrier. The pairs are rapidly divided by barrier strong field which has the value of $3\cdot10^5$ V/cm order. The carriers of one sign drift to surface charges and neutralize them and carriers of other sign pass through the layer up to approaching screening charges and also neutralize them.

The quantum yield of photogeneration of charge carriers η is determined as the ratio of Δn charge number generated by the light in the layer to ΔN number of absorbed light quantums. At layer lighting

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by monochromatic light ΔV surface potential decay is expressed by the formula $\Delta V = \frac{\Delta n \cdot e}{c}$. From here

$$\eta\lambda = \frac{\Delta n}{\Delta N} = \frac{\Delta V \cdot c}{e \cdot \Delta N} \quad (2)$$

where c is layer capacitance, e is elementary charge.

Knowing ΔV, c, e and ΔN one can calculate the spectral distribution of quantum yield η_λ by the formula (2).

EPh layers are prepared by dispersion of $CdInGaS_4$ crystal powder in polymer binder and by deposition of obtained suspension on metallic substrates. Before the fixing in sprinkling installation these substrates are unoiled by solvents, etched and preserved in acetone. The thickness of obtained layers is 20-40 μm and their main properties are study on electrometric installation with vibrating electrode near layer surface. The layer charging is carried out in corona discharge. The layer light characteristics are measured at exposure through shutter with the use of incandescent lamp and neutral filters. The source of monochromatic light is graduated by radiation compensated thermoelement PTH-30.

The layers at both polarities charge up to initial potential (600-700V) with its dark half-decay (1-2 min) at optimization of doping, thermotreatment, powder dispersion of photosemiconductor and its weight concentration. $CdInGaS_4$ layers with Au impurity have the value of integral sensitivity 0,4-0,9 $lux^{-1}\cdot sec^{-1}$ with low residual potential ≤ 30 V. In these layers the spectral sensitivity defined by the formula $S_\lambda = \left(\frac{1}{L_\lambda \cdot t}\right)_{\frac{\Delta V}{V}=\frac{1}{2}}$, $cm^2\cdot J^{-1}$ covers all spectrum visible part.

The layer quantum yield on base of $CdInGaS_4$ in the binder without Au impurity and with it calculated by formula (2) is shown in fig. 1. In the layers from undoped photosemiconductor the quantum yield rapidly increases as the quantum energy becomes enough for formation of electron-hole pairs and it is equal to ~0,85 almost up to 500nm.

At further increase of wave length the quantum yield decreases because of non photoactive radiation absorption of layer binder material (fig.1 a). The sensitivity in sensitization absorption band appears in $CdInGaS_4$ layers with Au impurity and value of quantum yield achieves 1 and covers the wide region in spectrum visible part (fig. 1 b).

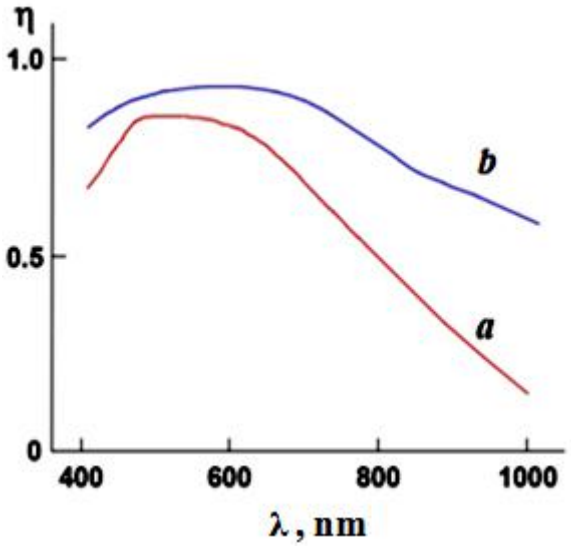

Fig.1. The spectral distribution of EPh layer quantum yield on $CdInGaS_4$ base without Au impurity (*a*) and with it (*b*).

We showed earlier [8-10] that the complex of photosensitivity phenomena the results of which gives the possibility to show the character of electron transitions in scheme form with three types of local centers (r and S are recombination centers and t is attachment level) in forbidden band, is observed in several crystals of $A^{II}B^{III}C_4^{VI}$ class including $CdInGaS_4$. Because of big difference of cross-section values of electron and hole capture r are centers being sensory centers: they rapidly capture non-main carriers and slowly capture the main ones that leads to strong monopolarity and high values of photosensitivity.

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