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The «Negative» Luminescence in Monocrystal $Cd_xHg_{1-x}Te$ With Own Conductivity

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Annotation. In the given publication a study is made of recombinative emanation of $Cd_xHg_{1-x}Te$ when concentration of charge carriers in emitting field becomes lower than the balanced value. Specificities of zone-zone photoluminescence in narrow zone solid solutions of $Cd_xHg_{1-x}Te$ under effect of the electric and magnetic fields have been experimentally examined.

The stationary and non-stationary processes of luminescence wise analyzed and mobilities of non-basic charge carriers determined.

Keywords: recombinative emanation, photoluminescence, narrow zone solid solutions, photo register, Planck's distribution, diffusive length, generation of charge carriers.

Introduction. Interest to study of solid solutions of $Cd_xHg_{1-x}Te$ and different structures on their base is conditioned by their wide use as receivers of IR-emanation and unique nature of physical properties-emergence of chinkless state, extremely high mobility and lower effective mass of electrons, pecularities of energetic spectrum of admixtures, a well their extraordinary sensibility to mechanical, temperature, radiation, electric and other effects.

General luminescence in semiconductors emerges as a result of illuminating recombination of non-balanced charge carriers, created by any external source of energy (with concentrations n and P) exceeding the balanced value $\left(n \cdot p > n_i^2\right)$. The density of recombinative emanation of non-degenerative semiconductor $P = P_0 \dfrac{n \cdot p}{n_i^2}$ exceeds own balanced value P_0 in this case. As $\Delta p = P - P_0 > 0$, then it is possible to call such luminescence conditionally «positive» one. Similar kind of luminescence is well-known and has a great number of the practical applications [1].

The present article is dedicated to the profound of one among insufficiently explored phenomena – the negative luminescence, the point of which is the following. Suppose that charge carriers are removed from semiconductor by any way using external source. In conditions of non-balanced exhaustion $\left(n \cdot p > n_i^2\right)$ the density of recombinative emanation will become lower than balanced P_0, i.e. $\Delta p<0$. It's easy to see that at reaching heavy exhaustion the measured value approaches to its maximum value P_0.

«The negative luminescence may be observed at various modes of non-balanced exhaustion of semiconductors, for instance at contact exclusion or extraction, magnetic concentration or effects relative to it. With this, the most suitable material are, as in case of the» positive luminescence, semiconductors with high quantum yield of radiating recombination.

The results on investigation of the negative luminescence may be applied to creation of the sources of IR-emanation based on $Cd_xHg_{1-x}Te$ monocrystals, running in a field of wavelengths of $8 \geq s \geq 10$ mcm. Therefore, investigation of recombinative emanation of $Cd_xHg_{1-x}Te$ presents scientific and practical interest.

Experimental results and their discussion

The objects of investigations were monocrystals of solid solutions $Cd_xHg_{1-x}Te$ with $0{,}30 \leq x \leq 0{,}40$, and as a method of ruling the concentration of charge carriers magnetic concentration effect was used. As a consequences of direct intra-zone emanating transitions an effect of self

Absorption in this material becomes much more than in the indirect zone semiconductors and condition ad>>1 is well observed. High concentration and greater mobility of charge carriers in $Cd_xHg_{1-x}Te$ permit to observe considerable modulation of recombinative emanation even at comparatively small governing an electric and magnetic H-fields. The concentration of charge carriers at side with low rate of surface recombination S may be considerably lower or higher than the balanced depending on direction of cross drift of electronic holey under effect of Lorentz′force. Luminescence signal (in the first case – OL, in the second case-general luminescence) conditioned by transitions in a field of self absorption was registered by photoregister $Cd_{0,2}Hg_{0,8}Te$, was amplified by an amplifier and entered to memory oscillograph. TOL avoid joule heats an electric field was attached to the samples as impulses of 1 mcs duration. The experiments were carried out in the temperature range T=200÷300 K.

The negative luminescence was investigated on thin (20÷30 mcm) plates $Cd_xHg_{1-x}Te$ with own conductivity. One of the wide sides of plate, from which emanation was observed, was subjected first to etching in solution HB_2+Br_2(90:100), and then also in the etchant $HCl+HNO_3$(97:3) and by our measurements was characterized by no high value of velocity of surface recombination $S_1 \leq 5 \cdot 10^3$ cm/s, the other surface was polished with small disperse diamond powder that provided much more value $S_2 \left(\frac{S_2}{S_1} \geq 10^2 \right)$.

Volt ampere characteristics of one of crystals, presented in Fig.1 testify to essential change of field number of charge carriers in examined crystals, existed in magnetic field H. (In the inserting of this figure a geometry of the sample and reciprocal assamgement of the electric and magnetic fields).

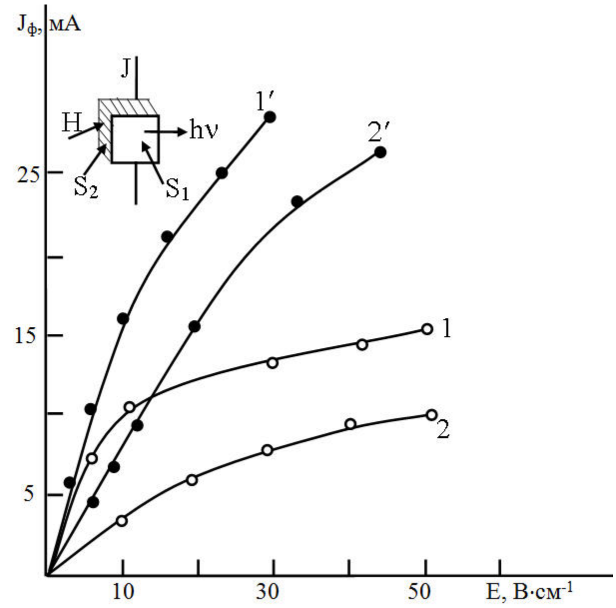

Fig. 1. VACh in $Cd_{0,4}Hg_{0,8}Te$ p in the cross magnetic field at T=200 K, H, kE: 1, 1′ – 2; 2, 2′, hachures without magnetic field. In the insertion scheme of experiment is given

Not dwelling on their discussion in details, we′ll note only they agree qualitatively with the results obtained during investigation of $Cd_xHg_{1-x}Te$ under same conditions [2÷4] and testify to considerable exhaustion of practically entire width of crystal in one direction of magnetic field H 9curves 1, 2) and at surface enrichment of a border with small velocity of surface recombination S in conditions of ____ recombination in other direction H (curves 1′, 2′).

In Fig.2 cited are the dependencies of power of recombinative emanation P, fixed to the balanced value P_0. Exhaustion conditions of emanating surface accompanied with the negative luminescence are shown by curves 1-4. As is seen, with an increase in electric field emanation of crystal at exhaustion diminishes the more quicher, the more higher a value of magnetic field, white at H≥3 kE runs to saturation.

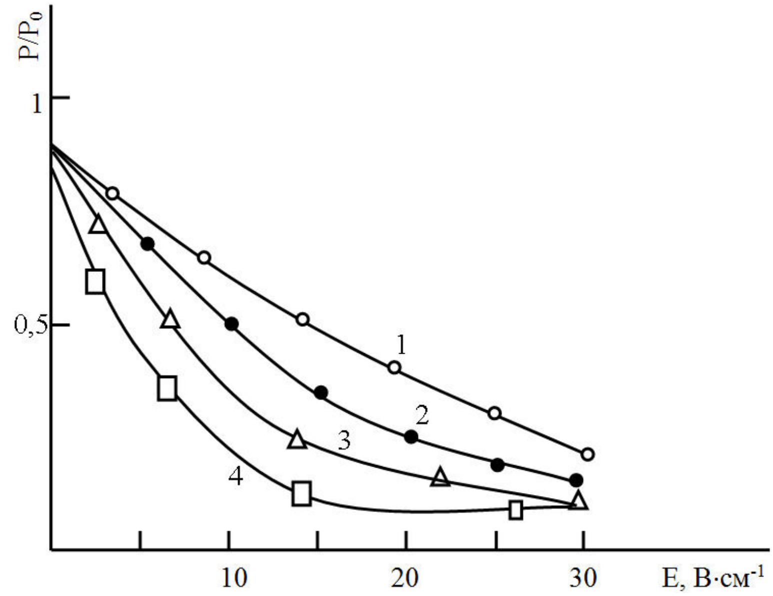

Fig. 2. Dependence $\frac{P}{P_0}$ of the negative luminescence on tensity of electric field for

$Cd_{0,4}Hg_{0,5}Te$ at T=200 K, H, kE: 1 – 1; 2 – 1,6; 3 – 2, 4; 4 – 3

The regions of saturation of curves 3-4 testify to that depth of modulation of recombinative emanation was reaching a value of the balanced emanation P_o and at time of duration of impulse of electric field zone-zone recombinative emanation from a border ceased. Measurement of the negative luminescence amplitude for $Cd_xHg_{1-x}Te$ crystals with 0,40 ≤ 0,60 gave the value (3÷0,9) mVm with 1 cm^2, as estimations showed analogical signal of general luminescence in $Cd_xHg_{1-x}Te$ is achievable only at using laver working in the conditions of modulated quality [5].

In Fig. 3 cited is dependence of power of the negative luminescence emanation on tensity of magnetic field for $Cd_xHg_{1-x}Te$ samples with x=0,4. the analysis of the figure shows that with increasing magnetic field P diminishes as H^{-1}, reaches minimum at value H, and then increases again. With increasing electric filed and velocity of surface recombination position of minimum shift to a region of greater magnetic fields.

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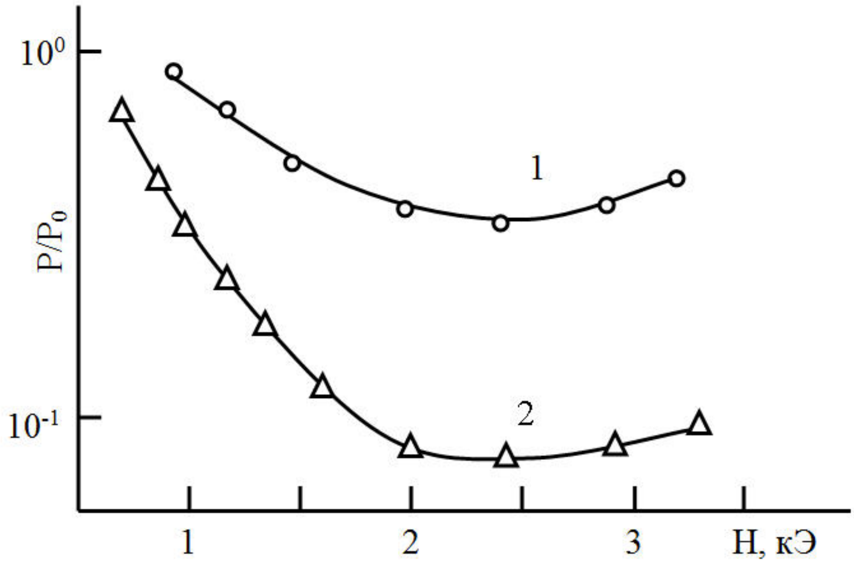

Fig. 3. Field dependences of the negative Luminescence T=200, K, E, V\cm;
1 – 12; 2 – 28

These experimental characteristics and minimum criteria are obtained theoretically in [6] and correspond to:

$$H_m = \left(\mu_n \cdot \mu_p \cdot \frac{H_{\sim}^2}{C^2} - 1\right) = \frac{4kTC}{e(\mu_n + \mu_p) \cdot \tau \cdot S \cdot E_x} \qquad (1)$$

In essence maximum signal of the negative luminescence is equal to power of the balanced emanation P^0 of material itself. With this emanation from a side lacks at switching electric magnetic fields and drift of electronic holey pairs into depth of crystal (saturation region of curves 3 and 4 Fig. 2) and for time of thermal generation of pairs increases till the balanced value P_0 after switching on field E. It is possible to estimate a value P_0 using Planck′s distribution for absolutely black solid within the limits E=25 V/cm. As showed calculations in [6] expression for P_0 is as follows:

$$P_0 = \frac{k \cdot T \cdot E_g^3}{4\pi^2 \cdot C^2 \cdot \hbar^3} \cdot e^{-Eg|k \cdot T} \left[1 + 3\frac{kT}{Eg} + 6\left(\frac{kT}{Eg}\right)^2 + 6\left(\frac{kT}{Eg^3}\right)\right] f(q), \qquad (2)$$

where f(q) is emanating quality of material, determining its indices of refraction q. At q=1, f=1, at q=3, f=0,663.

As experimental results showed transformation of spatial distribution of the non-balanced charge carriers under effect of Lorents′ force affords possibility of considerable conducting a value of external quantum emission of luminescence and its spectra as a consequence of optical coarse of zays in crystal. The obtained results agree well with calculation cited in [7].

Conclusion. It is possible to determine the mobility of charge carriers on basis of these results by Heins-Shockly method, that in our case makes um $3,5\cdot10^2$ gm^2/v.s. The phenomena considered may be perspective for creation of solid transformers of emanation permitting to change frequency of emanation and simultaneously to modulate the amplitude of outlet signal by means of external conducting fields.

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