Luminescence of CdS and CdTe Crystals at Pulse Irradiation by Electrons

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Abstract – The paper presents results of studying of change of a crystal transparency of CdS and CdTe under the influence of a pulse electron beam and pulse cathodoluminescence at temperature 295 K. It is shown, that the magnitude of a parameter of the induced absorption is comparable with a coefficient of optical intensification at the forced decay of excitons. The results of study of pulse cathodoluminescence at temperature 295 K pure and doped by chlorine crystals of CdTe are presented.

Presence of impurity and intrinsic structural defects in crystals A_2B_6 exerts significant influence on the form of near band – edge of fundamental optical absorption [1]. Change of a transmittance of crystals near band – edge of fundamental absorption at excitation by high – energy photons of the electromagnetic radiation, accelerated particles or intrinsic edge radiation can serve as the important factor determining an external energy yield of a luminescence [2]. However, until recently the nature and spectral distribution of the induced optical absorption in crystals A2B6 has been investigated obviously insufficiently.

The goal of the present work is the experimental research of pulse cathodoluminescence (PCL) and influence of CdS and CdTe crystals preparation on magnitude and spectral distribution of the induced optical losses. CdS crystals were grown by static Davydov – Markov method and CdTe – Obreilov – Shubnikov method of directed crystallization in Crystallography Institute of the Russian Academy of Science (Moscow).

For researches the method of pulse optical spectroscopy was used. The excitation of a luminescence was carried out by pulse electron beam (PEB) with the parameters: maximal electrons energy was 0,28 MeV; pulse duration on half height ~12 ns; the energy density (W_0) varied in the range 0,01 – 0,58 J/cm^2. The irradiation of crystals was carried out at temperature 295 K. Estimation of the induced optical absorption was obtained by measurement both of intensity PCL dependence from the linear sizes of a region of excited crystal and measurement of a absorption coefficient due to intensity reduction of a luminescence.

The registration circuit of PCL is shown in Fig. 1. Registration of radiation I_L was realized in a perpendicular direction to falling of PEB I_L and under a sharp angle to irradiated surface I_β.

The choice of the excitation means is caused by the PEB irradiation provides volumetric excitation of

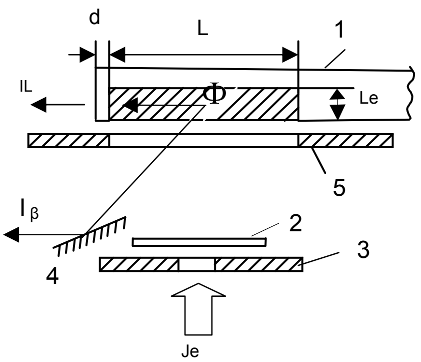


Fig. 1 Circuit of an irradiation and PCL registration of semiconductors: 1 – a sample, 2 – an aluminum foil (10 μm), 3 – a metal diaphragm, 4 – a mirror, 5 – a diaphragm assigning the sizes L of irradiation range

a sample. As since the electron tracks of PEB essentially exceeds thickness of a defective layer after mechanical or chemical mechanical polishing of samples the radiation contribution of a defective layer can be disregard.

In Figs. 2, 3 and 4 PCL spectra are submitted at different excitation density for CdS and CdTe samples. Excitation region of samples were identical and made 1x3 mm^2. The spectrum maximum of spontaneous radiation of CdS $I(\lambda)_L$ (curve 2, Fig. 2) is shifted to low energy range as compared with $I(\lambda)_\beta$ (curve 1, Fig. 2). This displacement is caused by absorption effect of PCL in the excitable volume of a crystal.

For the reduction of reabsorption effect and establishments of the radiation recombination mechanism the PCL spectra for excitation region with the small linear sizes (Fig. 3) are measured. However, as shown in Fig. 3, the differed spectra for two below the threshold of excitation density although show a spectrum determined by radiation exciton decay with a phonon nativity, but also are distorted by a reabsorption.

When the PEB energy density grows above some threshold magnitude, the PCL of CdS has the forced character that is appear in sharp super – linear intensity rise within a narrow spectral range and occurrence of direction external radiation. The radiation amplification in the investigated samples is primarily observed in region of phonon replica A – 2LO. With increase in excitation density the stimulated radiation maximum is shift in long – wave range and stabilized in the boundary of A – 3LO phonon replica. Threshold value of PEB energy density, halfwidth and maximum position of the stimulated radiation are own parameters of each sample and are defined by its preparation.

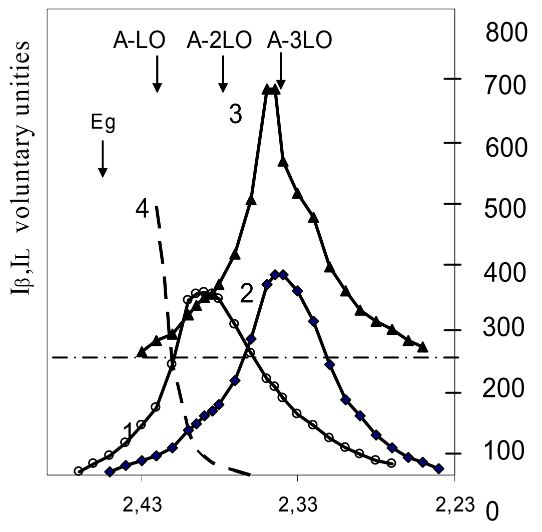


Fig. 2 Dependences of PCL spectra from an energy density of PEB and geometry of registration for crystal CdS: 1 – I_β (λ) at 0,028 J/sm^2; 2 – I_L (λ) at – 0,028 J/sm^2, 3 – I_L (λ) at 0,1 J/sm^2; 4 – α_C – calculated by Urbach rule [3]

Qualitatively similar regularities of PCL formation are characteristic for CdTe (Fig. 4). It is established, that real amplification of PCL with increase of excitation density is observed in the spectral region corresponding to the boundary A – 2LO phonon replica [4,5,6].

The passive absorption influence and excitation geometry and PCL registration for analysis of the phenomenological model of formation of spectral intensity of radiation in the excitable volume of a crystal [2] is used. In model the properties of a crystal were described by the spectral absorption coefficient α and the optical amplification factor γ_0. It has been shown, that real amplification of PCL is possible when performs a condition $\gamma_0 > \alpha$.

It is known, the maximal value of γ_0 corresponds to indirect transition at radiation exciton decay with a phonon nativity (A–LO region of phonon replica). However, in the investigated crystals increase in this spectral region was not observed, that directly confirms to presence of optical losses with absorption coefficient exceeded the amplification factor.

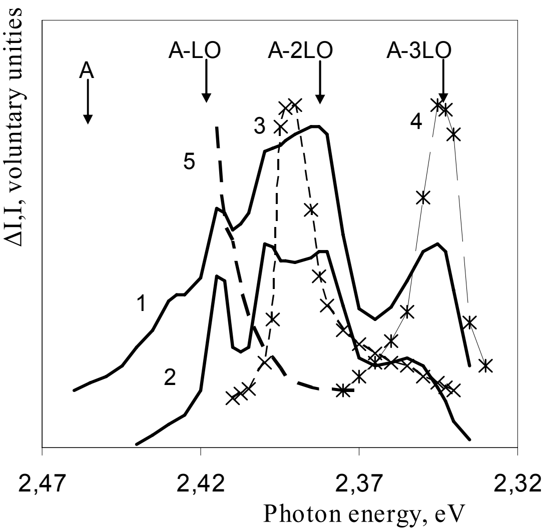


Fig. 3. Change of ΔI_L at increase of W_0 from 0,028 up to 0,034 J/sm^2 at l = 15 μm for: 1 – CdS (105), 2 – CdS (58), 3, 4 – I_L of CdS sample at W_0 = 0,065 and 0,58 J/sm^2 accordingly, 5 – α_C, calculated by Urbach rule [3]

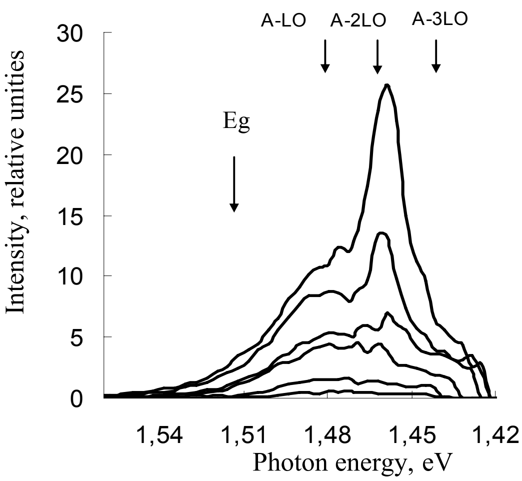


Fig. 4. Spectra of PCL I_L of undoped CdTe crystal at energy density of PEB (J/sm^2): 1 – 0,0042, 2 – 0,0079, 3 – 0,0124, 4 – 0,0169, 5 – 0,0306, 6 – 0,0442. It is numbered from the bottom to the top

Results of studying of transparency change of a crystal due to PCL reabsorption in region which is not excited by PEB (square d in Fig. 1) for CdS and CdTe crystals are submitted in Figures 5 and 6.

Spectral absorption coefficient dependences of CdS sample for two regions located on distances *d* of 95 and 186 μm from region, excited by PEB, are shown by curves 1 and 2 in Figure 5. From the offered results follows that action of the radiation generated in field of PEB influence on adjoining region of a crystal results in occurrence of the induced optical absorption of complex spectral structure K(hν), overlapped with PCL spectrum.

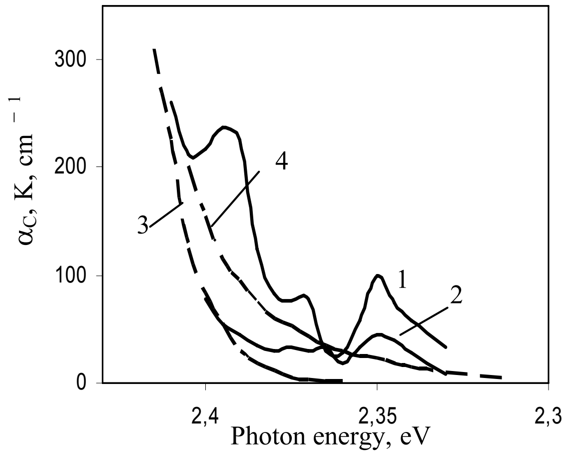


Fig. 5. Dependences of a absorption parameter K(hν) in CdS (23) from quantum's energy in the field of self – absorption edge at different distances from area of exciting PEB:1 – d = 95 μm, 2 – d = 186 μm, 3 – α_C (calculated on [3]); 4 – the absorption parameter measured for area in diameter of 5 mm by spectrophotometer SPh – 26

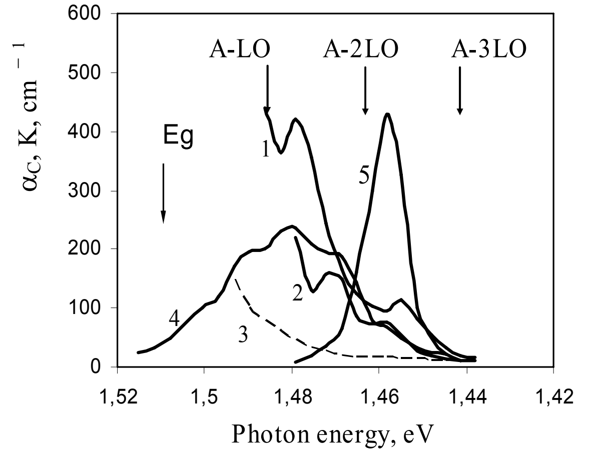


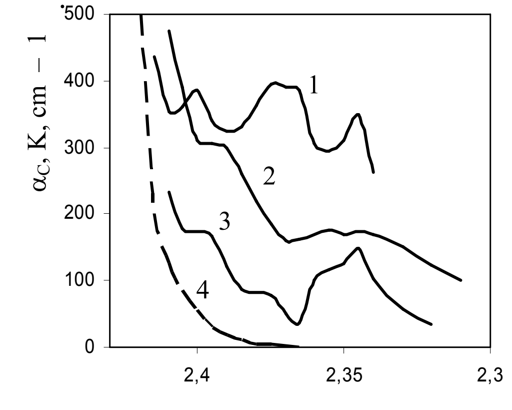
Fig. 6. Dependences of a absorption parameter in CdTe from quantum's energy in the field of self – absorption edge at different distances from area of influence PEB: 1 – l = 60 μm, 2 – l = 85 μm, 3 – α_C – it is measured at low radiations intensity on SPh – 26; 4 – PCL spectrum I_β and I_L at energy density of 0,009 and 0,044 J/cm^2 respectively

At a increase in distance from boundary of the irradiated region (or reduction of stimulating radiation intensity) decrease of size K(hν) which at large value *d* approximates to calculated value of a absorption coefficient α_C(hν) is observed [3,4] (curve 3, Fig. 5). The curve 4 in Fig. 5 corresponds to the absorption parameter determined on relative transmission of two samples with different thickness by a standard technique using spectrophotometer SPh – 26.

In Figure 6 curves 1 and 2 present dependences of a absorption parameter of CdTe crystal for two regions located on distance of 60 and 85 μm from a face of a crystal. With increase distance from a face of a crystal slump of K(hν) also is observed. The spectrum of the induced absorption mainly intercept spectral region corresponding to radiation exciton decay (A, A–LO and A–2LO bands [5,6]).

It is experimentally established, that the magnitude and spectral distribution of the induced absorption reveal the strongly dependence on thermal annealing condition in atmosphere of composition component and in vacuum. In Figure 7 spectral dependences of an absorption parameter for three CdS samples of different preparation are shown.

Annealing in vacuum (T = 695 K, 8 h) results in significant increase K(hν) and, as consequence, to increase in threshold excitation density corresponding to the stimulated luminescence. Annealing in atmosphere of cadmium also results in increase in an absorption parameter and appearance of long – wave displacement of transmission boundary and to increase in non – radiation recombination efficiency. At the same time annealing in a gas mixture of sulfur and helium ($P_s = P_{He}$ = 60,8 KPa, T = 695 K, 6 h.) results



Photon energy, eV

Fig. 7. Dependences of a parameter of absorption in CdS from energy of quantum in the field of self – absorption edge for three samples: 1 – annealing of CdS (23) in vacuum, 2 – annealing of CdS (51) in cadmium vapor, 3 – annealing of CdS (23) in a gas mix of sulfur and helium, 4 – α_C (calculated on [3])

in reduction of a absorption parameter in energy region 2,4 eV and to some increase in the region of 2,33 eV. Aside from reduction of threshold density of the excitation corresponding to the stimulated luminescence is observed.

Thus, influence of edge radiation results in appearance the induced optical absorption with complex spectral structure in the CdS and CdTe crystals. The magnitude of the induced optical absorption is defined by an excitation level and a sample preparation and comparable to optical amplification factor [5]. It determines threshold excitation density and spectral position of the stimulated radiation.

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