Nature of boundary radiation of α-*CdSe* layers obtained by isovalent replacement

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Abstract

Peculiarities of boundary radiation of α-*CdSe* layers are investigated by λ-modulation method. It is determined that dominating radiation is caused by annihilation of binding excitons. It is shown that residual atoms of sulfur's isovalent impurity take part in forming of excitons radiation.

Introduction

Cadmium Selenide is one of those not numerous semiconductors that are widely used as patterns when non-equilibrium processes in binary and more complex compounds are described. The vast information about the optical properties of the material existing in literature belongs to the stable hexagonal modification of α-*CdSe* [1]. The bands caused by the transitions with local centers dominate usually in the photolumi-nescence (PL) spectra of such patterns at the room temperature. The author observed the radi-ation of free excitons at the 300 *K* [2] for the first time in the polycrystalline α-*CdSe* synthesized using the high-clean elements. The similar effect was also exposed later in heterolayers of Cadmium Selenide made in monocrystalline backs of α-*CdS* by method of isovalent replacement. [3,4]. The PL spectra in the range 77-500 *K* are presented as intense boundary band possessing typical properties of exciton radiation. At the same time the question 'what is the nature of exciton' which was the base of the present examinations remains open.

Results and discussion

The λ-modulation method was used for the determination of the emitting recombination's features [5]. Let's note that the experimental arrangement admits the measuring not only in the base frequency modulation (the first harmonic) but also in the second harmonic. This made it possible to detect the subtle structure of PL spectra of the researching objects that do not appear in the ordinary radiation spectra $N_\omega(\hbar\omega)$ at all. All stated above is plotted in the Fig. 1 that will be examined more detailed.

The ordinary (unmodulated) PL spectrum is an asymmetric band which has halfwidth $\Delta\hbar\omega_{1/2}$ considerably lager than *kT* (Fig. 1a). This is the evidence of its complex structure which however does not become apparent on curves N_ω in any excitation level *L* at 77 *K*. Let's note that the excitation level could be changed in wide enough ($\sim 10^{14}$-10^{18} quantum/sec) range. The radiation's maximum $\hbar\omega_m$ shifts into law-energy spectrum field when *L* increases and this
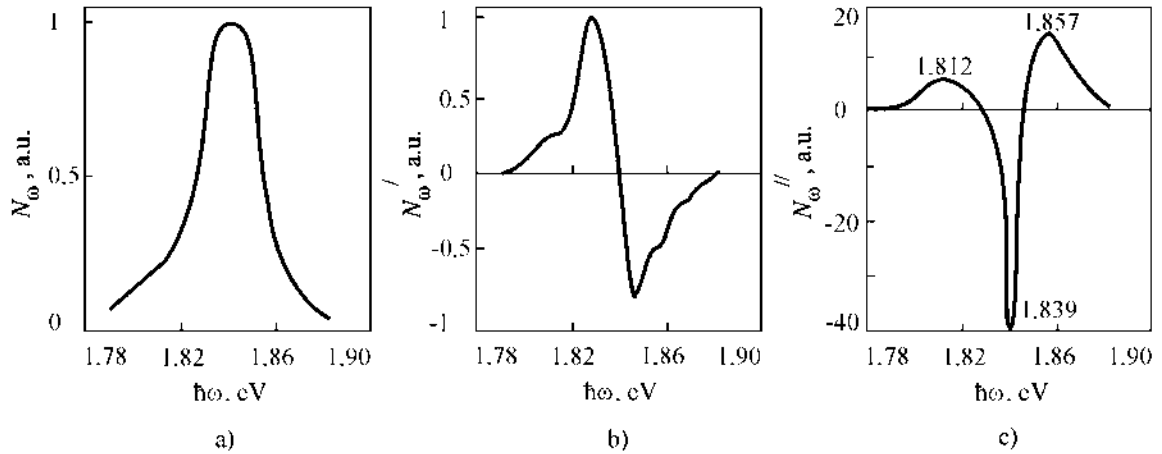
Fig.1. The photoluminescence spectra of α-CdSe layers at 77 K: (a) original spectra; (b) the spectrum of the first derivative; (c) the spectrum of the second derivative.

is the evidence of dispersion of exciton on the lattice's oscillations [6]. The modulated PL spectrum (the first derivative – $N_\omega^{/}$) contains the equidistant twists distance between each other is ~28 meV in law-energy region. This matches well enough with the energy of LO-phonons of α-CdSe ($\hbar\omega_0 \approx 28$ meV [7]). The difference between energy gap's width E_g and phononless line's maximum is about 18 meV. This value is close enough to the binding energy of a free exciton of α-CdSe which is equal 16 meV according [7]. In this case the halfwidth of phononless line must be equal to about 1.5 kT which is ~7meV at 77 K. The experimental value $\Delta\hbar\varpi_{1/2}$ (it was found from the spectrum of the second derivative - $N_\varpi^{\prime\prime}$) turned out to be equal ~4 meV (Fig. 1b) which is considerably less than expected halfwidth of a free exciton. So the results above are the testimony of the annihilation of binding exciton.

Let us clarify the nature of the center the exciton of which is binding with in the investigated layers. First of all let's note that the binding energy of the exciton $G_{d,a}$ with a neutral center for the II-VI compounds is defined by its ionization energy $E_{d,a}$ [7]

$$G_{d,a} = b \cdot E_{d,a}, \qquad (1)$$

where b=0.2 and 0.1 for the donors (d) and

acceptors (a) respectively. We discovered two donor's levels with the depth of occurrence equal to 200 and 700 meV in the investigated layers. The binding energy of the exciton with these centers is equal to 40 and 140 meV according (1) which is considerably more than experimental value $E_g - \hbar\omega_m \approx 18$ meV. The shallow levels of intrinsic defects of lattice (the internodal atoms of cadmium with $E_d \approx 20$ meV and selenium with $E_a \approx 100 meV$ [7]) can not take part in these processes as long as the expected values $G_{d,a}$ do not accord with experimental values.

The detailed research of structural and electrical properties of α-CdSe heterolayers showed that they are defined by isovalent sulfur's dope (ISD) in many respects (the residual atoms of base back of CdS). It is reasonably to admit that given ISD takes also part in forming of exciton's radiation. The base for this statement is the similarity of the basic parameters their characteristics of PL layers of α-CdSe and of GaP<N> that is well investigated from this point of view. It is shown in [8] that the radiation of excitons binding at this dope dominated under the nitrogen concentration of 10^{18}-$10^{19}cm^{-3}$. The results of the investigation of optical absorption testify that the ISD sulfur concentration is not less than 10^{19} cm^{-3} in α-CdSe layers. Let's also

note that the short-range ISD potential leads to a fact that the localization of charge carriers at this impurity is 1-2 orders more than at ordinary donor or acceptor. This provides the weak dependence of the responding exciton's bands radiation intensity that is observed for many materials containing ISD [8,9] including α-CdSe [10]. Activation energy E_T of temperature quenching of exciton's band in the investigated patterns turns out to be equal to 140 *meV* and it defines in the first approximation the distance between ISD and the nearest allowed energy band. Let's note that the sulfur forms deep acceptor in the Cadmium Selenide according to the Hopefield criterion [7]. In this connexion E_T is the depth of occurrence of the position of sulfur's level from the bottom of conduction band. At the same time more precise definition of energy and other parameters of ISD sulfur in Cadmium Selenide requires separated researches, which exceed the bounds of given paper.

Conclusions

The described results testify the dominant role of residual atoms of sulfur in the forming of boundary radiation of Cadmium Selenide heterolayers synthesized by the method of isovalent replacement in α-CdSe backs.

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