The Nature of the Edge Emission Bands of n-CdSe/mica Epilayers

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***Abstract* – We study the spectra of the boundary cathodoluminescence of n-CdSe undoped epilayers grown in a quasi-closed system on mica cristals. It was established that in the layers obtained at the evaporation temperature of 650° C substrate temperature of 480° C and the density of the excitation current j = 0.5 A/cm^2 on the long wave wing of the edge emission bands appear equidistant lines associated with LO - phonon replicas non-phonon line, due to the radiative capture of the band electrons by acceptor Vcd - center of the CdSe crystals.**

***Key words* – acceptor centers, cathodoluminescence, Alentsev - Fock method, edge emission, radiative recombination, cadmium vacancies (Vcd), epilayer.**

I. INTRODUCTIONS

Epilayers compound semiconductor CdSe have an important place in modern solid-state electronics, which is connected with wide variety of electrical, photoelectrical and optical properties. A characteristic feature of epilayers of CdSe is the possibility to form these layers in various types of point defects, impurity, intrinsic and packing defects. They often play a positive role: for example, point defects can be centers of luminescence and photoconductivity. It allows using epilayers n-CdSe as a base source for semiconductors and a position-sensitive photodetectors of visible light [1, 2]. In the work [2] is shown the spectra of the edge cathodoluminescence (CL) of the specially undoped epilayers of n-CdSe, grown in a quasi-closed system on mica cristals under different thermal conditions of epitaxy. The aim of this work is to study the mechanisms that are responsible for their band edge emission and special centers that are determined by its nature and physical properties formed during epitaxy and excitation of n-CdSe layers.

II. EXPERIMENTAL

Growth of CdSe layers.

Photoconductive CdSe layers were grown by hot-wall deposition in a quasi-closed system on mica layers in vacuum (residual pressure of $1.33 \cdot 10^{-2}$ Pa) and at temperatures closed to thermodynamic equilibrium.

Source temperature was maintained at T_{ev} = 650, 680° C and the substrate temperature was varied in the range (480 ÷ 600)° C. Surface area of the epitaxial layers was 3 cm^2. The source material for growing layers was CdSe powder marked as extrapure-grade which is previously sublimated in vacuum. CL spectra of CdSe layers were studied at 78 and 300 K. Excitation of the layers was performed by a pulsed electron beam with a specific pulse power of 3 kW/cm^2 at an average power of 0.2 W. Spectra were recorded with use of a monochromator DFS - 12 with a precision of 1 meV.

III. RESULTS AND DISCUSSION

Figure 1 shows CL spectra at 78 K of the epitaxial layer n-CdSe grown at an evaporation temperature T_{ev} = 650° C and substrate temperature T_s= 480° C [$\gamma = (T_{ev} - T_s)/T_{ev} = 0.26$].

The narrow intense line of the edge emission XA (1.810 eV) corresponds to the radiative recombination of free A-excitons in the state n = 1 [3]. The half-width of the line ΔW is determined by the thermal spread excitons by having a characteristic for this case the value of ΔW = 12 meV ≈ 1.8 kT.

The band edge emission in the λ = 710 ÷ 745 nm with a maximum at a photon energy ε_{F0} = 1.722 eV, in our opinion, is caused by radiative recombination of nonequilibrium charge carriers in the intrinsic dot defects. It may be assumed that such centers are cadmium vacancies (Vcd), playing a role of acceptor centers in epitaxial layers n-CdSe.

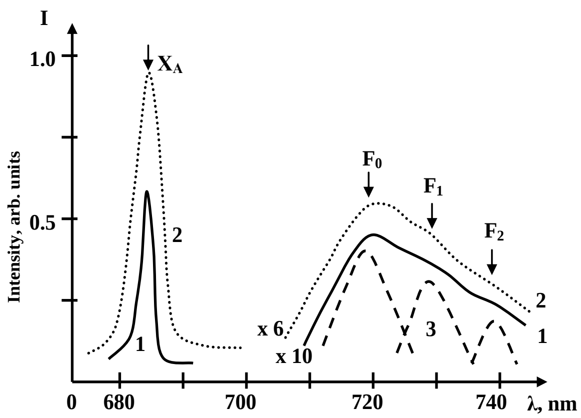

Fig.1. Cathodoluminescence spectra (78 K) of n-CdSe/mica epilayers shot at the electron beam energy of 40 keV and a current density of excitation (A/cm^2): 1 - 0.05; 2 - 0.5; 3- individual lines obtained by method Alentsev – Fock after decomposition of the CL spectrum.

This is supported by the fact of coincidence the energy difference between the bandgap crystals of cadmium selenide equal ε_g (78 K) = 1.826 eV, and the spectral position of the main band maximum (ε_{FO}) with ionization energy of 0.104 eV = Δεi Vcd in crystals of cadmium selenide [5]. By increasing the current density of the excitation (line 2) the intensity of the edge emission of the impurity band increases.

Form of the long-wavelength band edge emission layers n-CdSe/mica suggests that it is not elementary, and is formed by the overlap of its lines F_0, F_1, F_2. Based on this assumption, we used the method Alentsev - Fock [3] for the decomposition of the impurity band into individual lines. The method is based on the fact that if you change the shape of the excitation conditions similar in their spectral position overlapping, lines of emission deformed. A comparative analysis of different spectra of impurity CL, taken at two levels of excitation (curve 1, 2), allowed to find the position in the spectrum of each individual component.

Presented in Figure 1 lines 3 reflect a form of individual spectral lines CL n-CdSe layer in the area λ = 710 ÷ 745 nm. They correspond to the non-phonon line F_0 (718 nm) and its first F_1 (729 nm) and the second F_2 (740 nm) LO - phonon repetition whose energy is 26 meV. This character of the impurity band edge emission was observed in crystals of CdSe [5].

As it is known [2], in the n-CdSe/mica layers grown at high temperatures of epitaxy in conditions closed to thermodynamic equilibrium, the spectra of the boundary CL at 78 K is observed the emission band of free excitons only. At the same time as we approach to the technology of growing layers to high-temperature regime of epitaxy, their dark electrical conductivity significantly decreased. In our opinion this regularity is not connected with the process of preferential compensation of shallow donors by shallow acceptors, in our case as Vcd act. High-temperature cleaning of the source material from uncontrollable donor impurity is obviously crucial in a sharp decrease in the equilibrium conductivity n-CdSe/mica layers with an increase in their processing temperature [7].

IV. Conclusions

The main results of experimental studies of edge emission bands of epitaxial layers of n-CdSe/mica are as follows:

1. CL spectra (78 K) epitaxial n-CdSe epilayers grown in quasi-closed system at high temperatures in conditions close to equilibrium (T_{ev} = 680° C, T_s = 600° C), there is only the emission line of free A-exciton, which indicates high purity and crystalline perfection of the layers, that means the high-temperature cleaning of the source material from uncontrollable donor impurity.

2. By lowering the substrate temperature down to T_s = 480° C (T_{ev} = 650° C) impurity band edge emission appears in the radiation spectrum of CL in the area λ = 710 ÷ 745 nm.

3. Based on the procedure of decomposition of the impurity band edge emission n-CdSe/mica epilayers, it was established that it is formed by LO - phonon replicas of non-phonon line of radiative capture of electrons of the conduction band of n-CdSe by its Vcd - acceptor centers.

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