HETEROLAYERS OF CUBIC CADMIUM SULFOSELENIDES WITH A SURFACE NANOSTRUCTURE

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INTRODUCTION

II-VI heterostructures of CdS and CdSe compounds are important in modern functional electronics. On their basis, devices were created, the functionality of which is significantly expanded when surface nanostructures are created. At the same time, it is also important to expand the nomenclature of these materials by obtaining an atypical cubic modification. Existing technological processes do not provide the possibility of manufacturing devices with stable properties over time. Therefore, an urgent task is the selection of a method of obtaining atypical modification of CdS and CdSe, the formation of surface structures based on them, and the determination of their basic properties and possibilities of practical use [1].

RESULTS AND DISCUSSIONS

It was established that the method of obtaining heterolayers of cadmium sulfoselenides is the process of replacing the corresponding atoms in the basic substance with isovalent impurities

$$\beta\text{-CdS: } ZnS_s + Cd_i = CdS_s + Zn_i$$

$$\beta\text{-CdSe: } ZnSe_s + Cd_i = CdSe_s + Zn_i$$

At the same time, the classical process of diffusion from the gas phase in a closed volume is possible. Their optimal temperatures of 800-1100 °C have been determined, and the duration of the process also ensures a change in the thickness of the heterolayers. It was determined by means of well-known classical methods. The corresponding basic parameters were established by the methods of modulation spectroscopy [2]. The use of the λ-modulation method made it possible to study the energy structure based on the absorption spectra T'_ω and reflection R'_ω and establish fundamentally important parameters - the band gap E_g and the value of spin-orbital splitting of the valence band into subbands Δ_{so}, that is a characteristic of a cubic structure. Thus, E_g = 2.02 eV and Δ_{so} = 0.37 eV for β-CdSe and E_g = 2.90 eV with Δ_{so} = 0.30 eV for β-CdS are determined, Fig. 1.

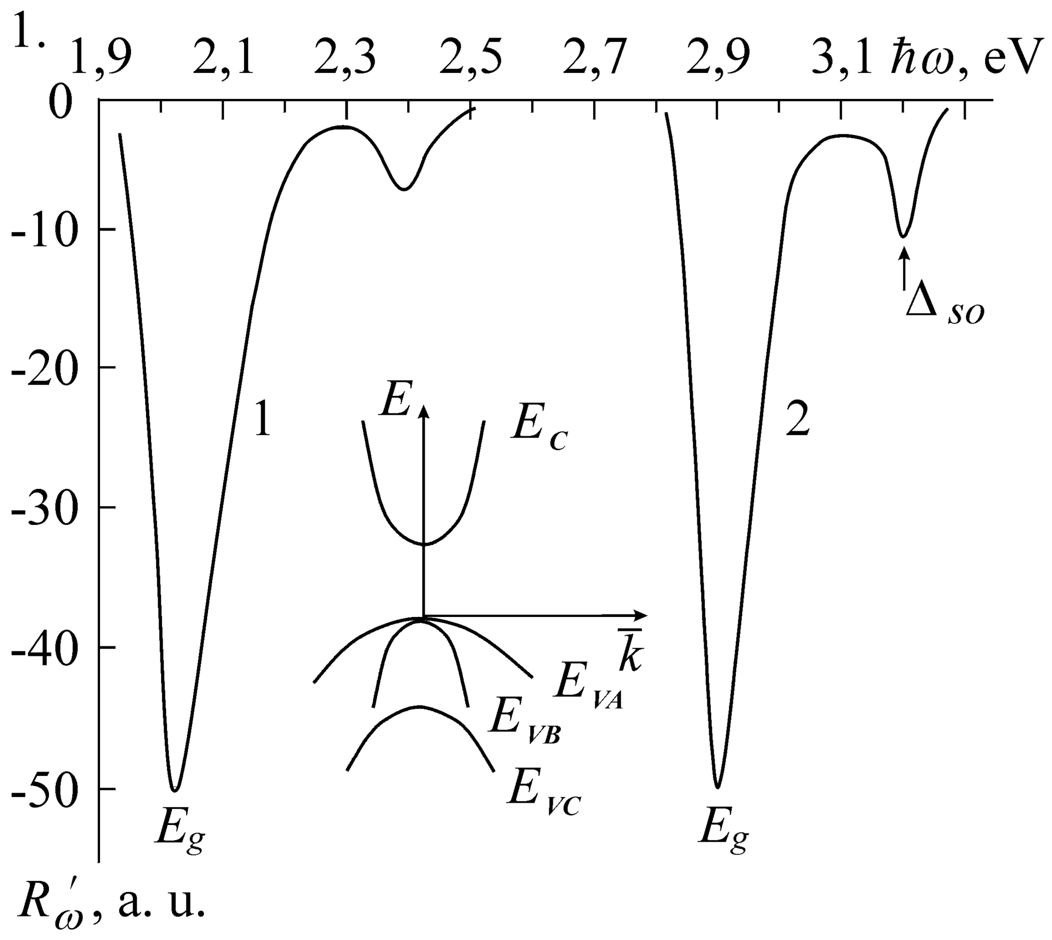

Fig. 1 Differential reflectance spectra of β-CdSe (1) and β-CdS (2) heterolayers at 300 K. The inset shows the structure of energy zones, which is characteristic of the cubic modification of the crystal lattice.

Nanostructured surfaces of heterostructures were formed by chemical etching of initial substrates in a H_2SO_4:H_2O = 3:1 solution. Selection of the duration and temperature of the treatment made it possible to form the appropriate morphology of the surface. It was determined by AFM topograms using an NT-206 atomic force microscope and consists of nanopyramids, the sizes of which vary within 2-5 μm, Fig. 2. Additional geometric structures were also formed on them.

The experimental research has established the presence of highly efficient photoluminescence (PL) with a quantum yield of η = 7-15%.

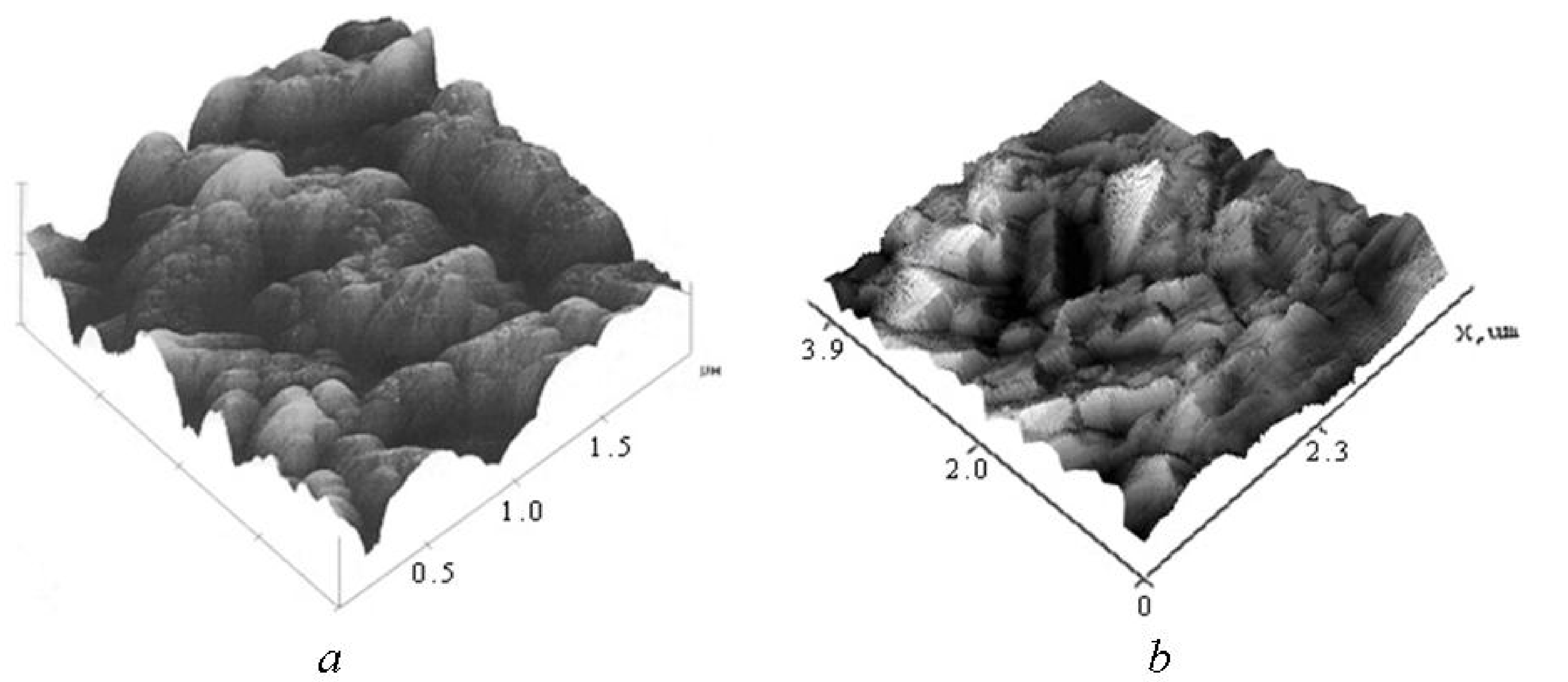

Fig. 2. AFM surface topograms of β-CdSe (a) and β-CdS (b) substrates annealed at optimal conditions.

The PL spectrum is characterized by a range of photons with energy $\hbar\omega \geq E_g$, Fig. 3.

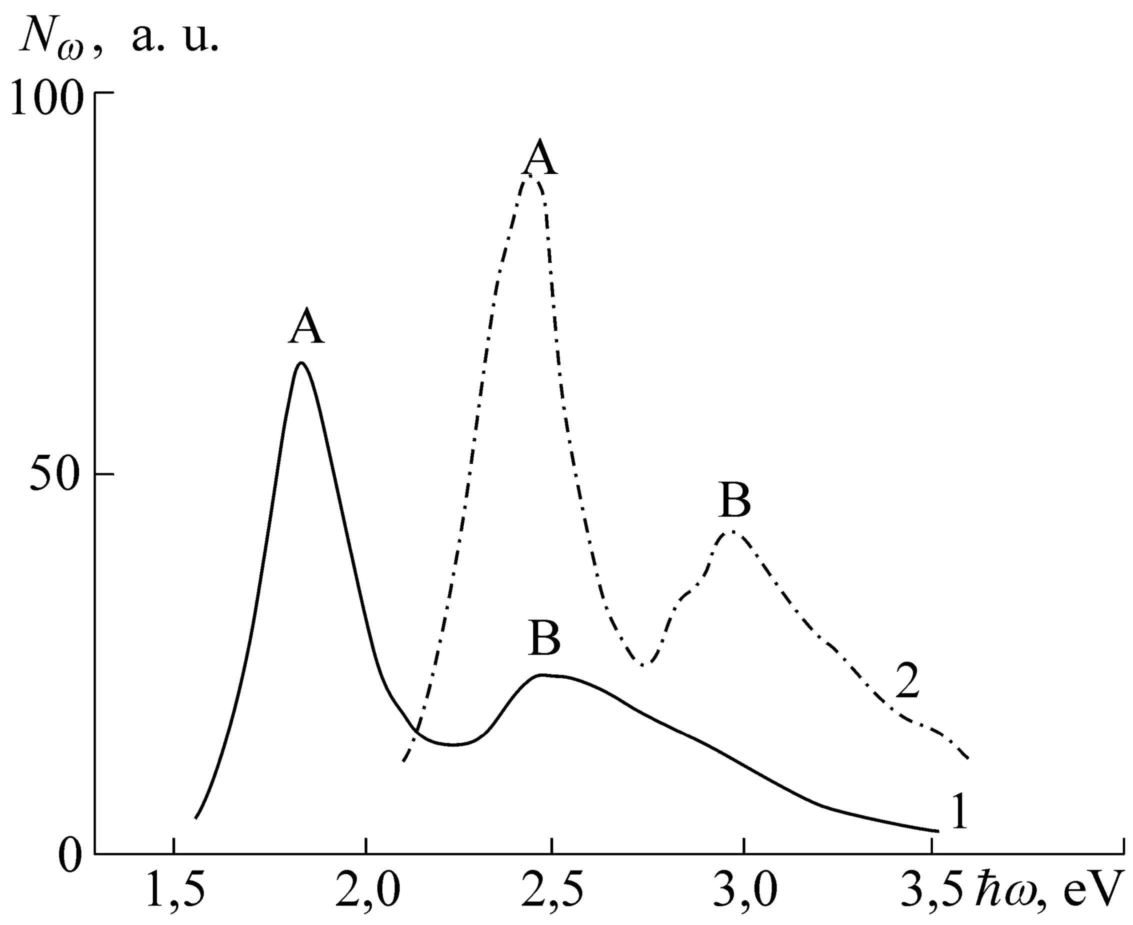

Fig. 3. Photoluminescence spectra of substrates with a modified surface: 1 – β-CdSe, 2 – β-CdS.

The existence of two regions in PL spectra at $\hbar\omega \sim E_g$ (range A) and $\hbar\omega \geq E_g$ (region B) is important. An analysis of possible mechanisms of intense radiation formation was carried out. As a result, it was established that at $\hbar\omega \sim E_g$ the dominant process is the process of interband radiative transitions of free charge carriers, which is well approximated by a well-known analytical expression

$$N_\omega \sim (\hbar\omega)^2 \sqrt{\hbar\omega - E_g}\, \exp\left(-\frac{\hbar\omega - E_g}{kT}\right) \qquad (1)$$

The region B with $\hbar\omega \geq E_g$ is characterized by a large width. In it, radiation is generated as a result of processes during quantum-mechanical transitions. The spectra of the corresponding band of radiation are approximated by the distribution obtained according to the known theoretical expression

$$\hbar\omega_m^B - E_g = \frac{\pi^2 h^2}{2d^2}\left(\frac{1}{m_n^* + m_p^*}\right) \qquad (2)$$

CONCLUSIONS

Thus, heterolayers with stable properties of atypical cubic modification of CdS and CdSe compounds can be obtained by the method of isovalent substitution. Their surface nanostructured layers can be formed by chemical etching. Properties and basic energy parameters of modified heterolayers can be determined using the λ-modulation method. Important for their practical use is highly intense luminescence with η = 7-15% in the edge region, which is formed by interband recombination and radiative transitions during quantum mechanical processes.

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[2] *Makhniy V.P., Slyotov M.M., Stets E.V., Tkachenko I.V., Gorley V.V., Horley P.P.* Application of modulation spectroscopy for determination of recombination center parameters // Thin Solid Films. - 2004. - **450**. - P. 222-225.