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Properties of CdSe heterolayers obtained by isovalent substitution on CdTe substrates

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Abstract. Using the isovalent substitution method, CdSe heterolayers of cubic modification were obtained for the first time on single-crystal CdTe substrates, and their basic physical properties were studied.

Keywords: isovalent substitution, heterolayers, cubic modification, physical properties.

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Cadmium telluride-based heterostructures can serve as a basis for efficient detectors of electromagnetic radiation in various spectral ranges, including solar range [1]. Another component of heterostructure in the latter case must be a wider-gap semiconductor with its crystal structure close to the lattice of cubic cadmium telluride, i.e. β -CdTe. The misfit in these parameters causes appearance of defects at the interface that considerably deteriorate characteristics of devices based on heterostructures. As long as the concentration of surface defects also depends on the heterostructure fabrication method, the choice of the latter is a relevant task, especially for materials with a considerable mismatch between lattice constants and thermal expansion coefficients.

Promising in this aspect is the isovalent substitution method that allows to considerably reduce the effect of mismatch between crystal and thermal parameters of heterostructure components on their characteristics [2]. In particular, this method was used on CdS and ZnSe substrates to synthesize CdSe heterolayers of hexagonal and cubic modification with efficient exciton luminescence at 300 K [3]. At the same time, no information can be found in literature on the properties of CdSe layers obtained by the isovalent substitution method on cadmium telluride substrates. In our opinion, it was caused mainly by the conclusion made by the authors of the work [4] on the nonsymmetrical character of processes occurring in the single crystals of wide-gap II-VI compounds with the isovalent substitution. According to it, heterolayers are always formed with the substitution of metal atoms, and in case of chalcogen (S,

Se, Te) only when substituting atoms have greater radius. It means that Te atoms can replace S and Se, and Se atoms can replace S (but not vice versa). In this relation, according to [4], the isovalent substitution method cannot be used to obtain CdSe heterolayers on CdTe substrates. Having modified technology, we managed to prepare CdSe/CdTe heterostructures [5] the basic properties of which are described in this paper.

The initial substrates were plates with sizes $4 \times 4 \times 1$ mm cut of the bulk n-CdTe crystals of cubic modification. The substrates were subjected to stepwise mechanical and chemical polishing in $K_2Cr_2O_7:H_2O:HNO_3 = 4:20:10$ solution, washing in distilled water and drying. Cadmium selenide heterolayers were created by the isothermal annealing of CdTe plates in saturated selenium vapors. The process took place in evacuated to 10^{-4} Torr and sealed silica ampoule within the temperature range 500 to 800 °C.

Investigations showed that after annealing a new chemical compound is formed on the substrate surface. It was confirmed by the analysis of differential spectra of optical reflection R'_ω , Fig. 1. As it is evident from the data, R'_ω are curves with definite minima which correspond to the energy gap widths E_g of cadmium telluride (~ 1.5 eV, curve 1) and cubic cadmium selenide (~ 2.0 eV, curve 2) [6]. Note that the position of minimum in the curve 2 does not depend on the annealing temperature T_a within the range 500 to 800 °C, inset in Fig. 1. It is also noteworthy that increase in T_a causes erosion of the substrate structure, and at $T_a < 500$ °C the surface has a heterogeneous island-like

structure. The thickness of resulting CdSe heterolayer is a function of temperature and annealing time and is limited by diffusion processes at isovalent substitution [3]. At the same time, determination of parameters of these processes for CdSe/CdTe heterostructure is beyond the scope of this paper and requires a special research.

Another peculiarity of synthesized layers is presence of intensive photoluminescence, the efficiency of which at 300 K can reach 15%. At room temperatures, the photoluminescence spectrum is represented by a wide band with a maximum close to $\hbar\omega_m \approx 1.74$ eV (Fig. 2), position of which does not depend on the annealing temperature (inset in Fig. 1). At the same time, the luminescence efficiency essentially depends on T_a , reaching the maximum value at $T_a \approx 600$ °C (inset in Fig. 2). As long as $\hbar\omega_m$ is distinctly smaller than E_g of CdSe heterolayer, this testifies in favour of recombination with participation of local centres. It is also confirmed by the sufficiently large half-width (~ 0.1 eV) of its radiation band and a weak dependence on measurement temperature. The estimate of the energy position of recombination centres from the relation $E_g - \hbar\omega_m \approx 0.26$ eV shows it to be deep.

Note the presence of a band with the maximum $\hbar\omega \approx 2.0$ eV in the heterolayer low-intensity luminescence spectrum (Fig. 2). Its position is consistent with a minimum in the differential reflection spectrum (curve 2 in Fig. 1), and with E_g value of cubic cadmium selenide at 300 K [6]. On the other hand, the radiation band in question with $\hbar\omega \approx 2.0$ eV is not present in CdSe heterolayers obtained by the isovalent substitution method on the substrates of hexagonal CdS [3]. Thus, the results obtained when researching the reflection and luminescence spectra testify in favour of the cubic structure of cadmium selenide layers created by isovalent substitution of selenium in cadmium telluride.

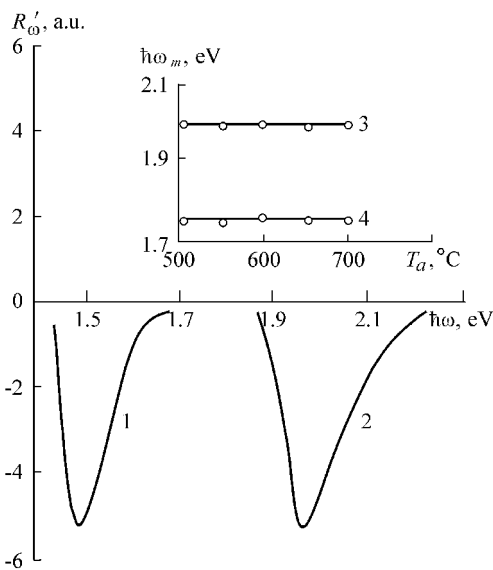


Fig. 1. Differential reflection spectra of CdTe substrates (1) and CdSe layers (2) at 300 K. The inset shows dependences of peak position maximum in curve 2 (3) and peak in the radiation spectrum (4) on temperature of synthesis.

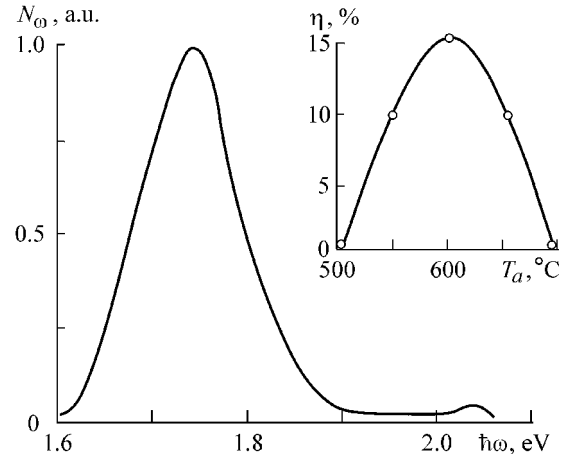


Fig. 2. Luminescence spectrum of CdSe layers at 300 K. The inset shows dependence of the radiation efficiency on temperature of synthesis.

We note finally that heterolayers possess a low electron conductivity, for which reason the synthesized CdSe/CdTe structures are little suitable for using them as photoconverters or light emitting diodes. Therefore, further research should be primarily oriented at looking for technologies of doping CdSe layers with high hole or electron conductivities. It stands to reason that in the latter case crystalline p-CdTe should be used for making the substrates.

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