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Influence of Laser Radiation on Optical Properties of High Resistivity Crystals CdTe and Solid Solutions $Cd_{1-x}Zn_xTe$

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In this paper, the transmission and reflection spectra of *p*-CdTe (111) single crystals; solid solutions of $Cd_{1-x}Zn_xTe$ (x = 0.1) in the range (0.2 - 1.7)·10^{-6} m before and after laser irradiation at the wavelength λ = 532 nm in the energy range (66 – 164) mJ/cm^2 for CdTe (111) and in the energy range 46.6 mJ/cm^2-163.5 mJ/cm^2 for $Cd_{1-x}Zn_xTe$ (x = 0.1) are measured. It is established that the main mechanism of influence of pulsed laser irradiation on the optical properties of thin surface layers of the investigated crystals is structural gettering, that is, the absorption due to the presence of sections of semiconductors that have a defective structure and have the ability to actively absorb point defects.

Key words: CdTe, CdZnTe, transmission, reflection, absorption, laser irradiation.

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Introduction

Semiconductor materials $A^{II}B^{VI}$, including CdTe and $Cd_{1-x}Zn_xTe$, is one of the most promising materials that are used for different kinds of detectors of ionizing radiation [1-4].

I. Experimental results and their discussion

In this paper, the transmission and reflection spectra of single crystals *p*-CdTe (111) with specific resistivity ρ = (2÷5)·10^9 Ω·cm are measured to elucidate the mechanisms of the influence of pulsed laser irradiation on thin surface layers of semiconductors; solid solutions $Cd_{1-x}Zn_xTe$ (x=0.1) with specific resistivity ρ = (0.5 ÷ 3)·10^{10} Ω·cm in the range (0.2 - 1.7)·10^{-6} m before and after laser irradiation at the wavelength of λ = 532 nm in the energy range 66 - 164 mJ/cm^2 for CdTe(111) and in the energy range 46.6 - 163.5 mJ/cm^2 for solid solutions $Cd_{1-x}Zn_xTe$ (x = 0.1).

In Fig. 1 shows the optical transmission spectra of *T = f (λ)* single crystals of *p*-CdTe (111) with a specific resistance of (2 ÷ 5)·10^9 Ω·cm (original sample is curve 1 and the samples are irradiated with energy of 66 mJ/cm^2; 108 mJ/cm^2, 164 mJ/cm^2 - curves 2-4 respectively). As can be seen from the figure, the transmittance of single crystals of *p*-CdTe (111) decreases only when irradiated with an energy density of 108 mJ/cm^2. In laser processing of these samples energy densities of 66 mJ/cm^2 and 164 mJ/cm^2 transmittance is almost identical to that of the original samples. This experimental fact shows that in this laser treatment of single crystals of *p*-CdTe (111) in the optical spectra the main role is played by thin surface layers of the investigated material, i.e. changes occurring near the surface of the semiconductor material.

In Fig. 2 shows the optical transmission spectra of *T = f (λ)* solid solutions $Cd_{1-x}Zn_xTe$ (x = 0.1) with a specific resistance of (0.5 ÷ 3)·10^{10} Ω·cm (original sample is curve 1 and the samples are irradiated with energy of 46.66 mJ/cm^2; 102.3 mJ/cm^2, 163.5 mJ/cm^2 - curves 2-4 respectively). As can be seen from the figure, the irradiation of solid solutions of $Cd_{1-x}Zn_xTe$ (x = 0.1) with energy densities of 46.66 mJ/cm^2 and 102.3 mJ/cm^2 significantly reduces the transmittance of this solid solution compared to the original samples, and with laser processing the energy density of 163.5 mJ/cm^2 solid solutions of $Cd_{1-x}Zn_xTe$ (x = 0.1) transmittance is

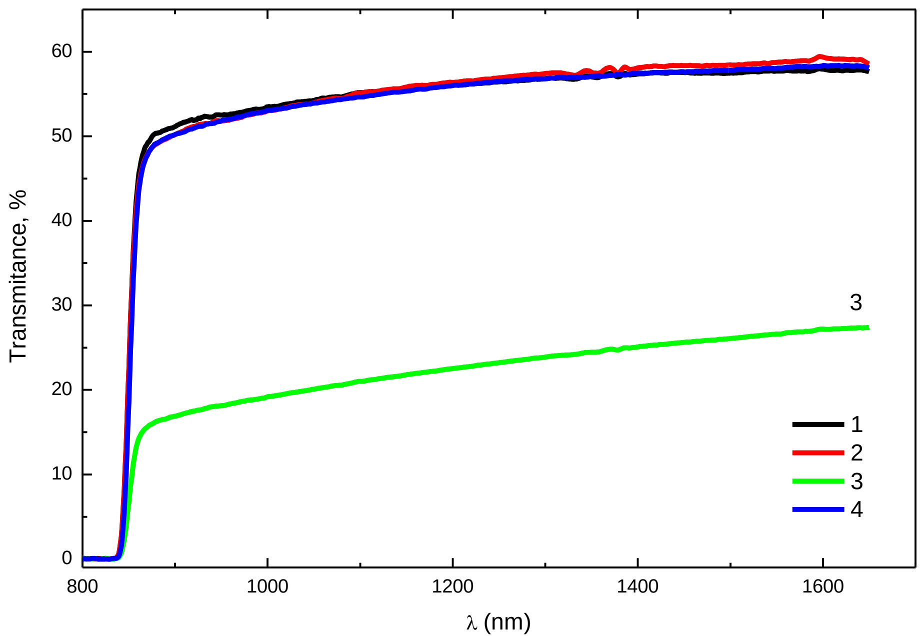

Fig. 1. Transmission spectra of single crystals *p*-CdTe (111): original sample is curve 1 and the samples are irradiated with energy of 66 mJ/cm²; 108 mJ/cm², 164 mJ/cm² - curves 2-4 respectively.

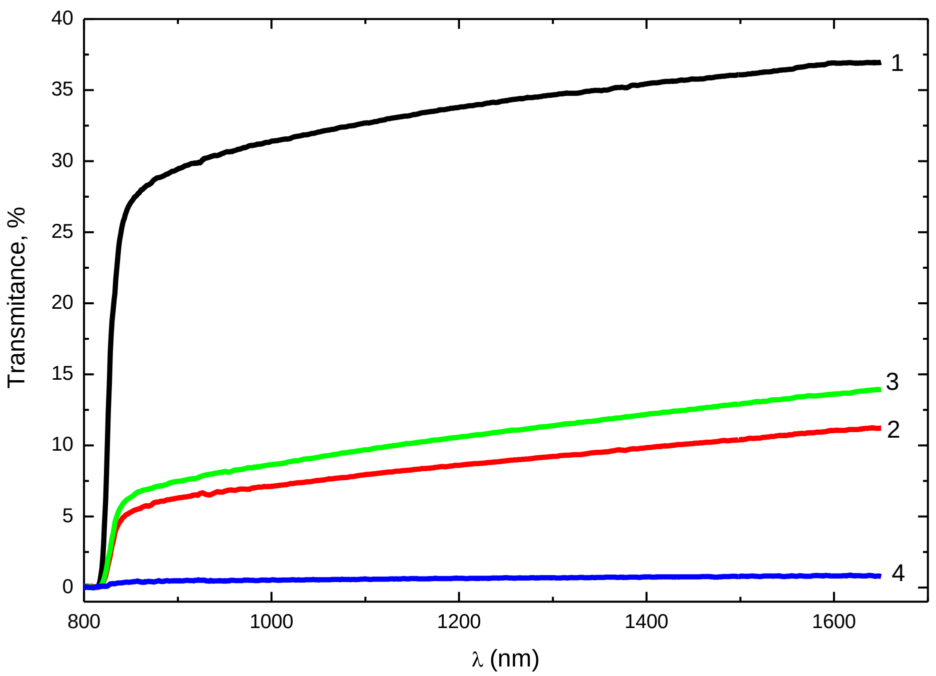

Fig. 2. Transmission spectra of solid solutions $Cd_{1-x}Zn_xTe$ (x = 0.1): original sample is curve 1 and the samples are irradiated with energy of 46.66 mJ/cm²; 102.3 mJ/cm², 163.5 mJ/cm² - curves 2-4 respectively.

practically zero (curve 4).

In [5, 6] it was observed that the spectra of optical reflection (Figs. 3, 4) of single crystals of *p*-CdTe (111) and solid solutions $Cd_{1-x}Zn_xTe$ (x = 0.1) showed that at a given laser treatment there is a laser-stimulated increase in the reflectivity of these semiconductor materials (the integral effect is explained by the differences in the optical characteristics of the surface layer and the volume material, that is, the complex refractive index of the surface layer $\tilde{n}_S = n_S + i\chi_S$ is different from the complex refractive index of the volume material $\tilde{n}_V = n_V + i\chi_V$).

Since the reflection coefficient $R = f(\lambda)$ is related to the transmittance $T = f(\lambda)$ and the absorption coefficient $D = f(\lambda)$ by the ratio $R+T+D = 1$ (thus the scattering of the light wave in the sample is not taken into account), the absorption spectra $D = 1-(R+T)$ of the light (electromagnetic) wavelength λ are also constructed in

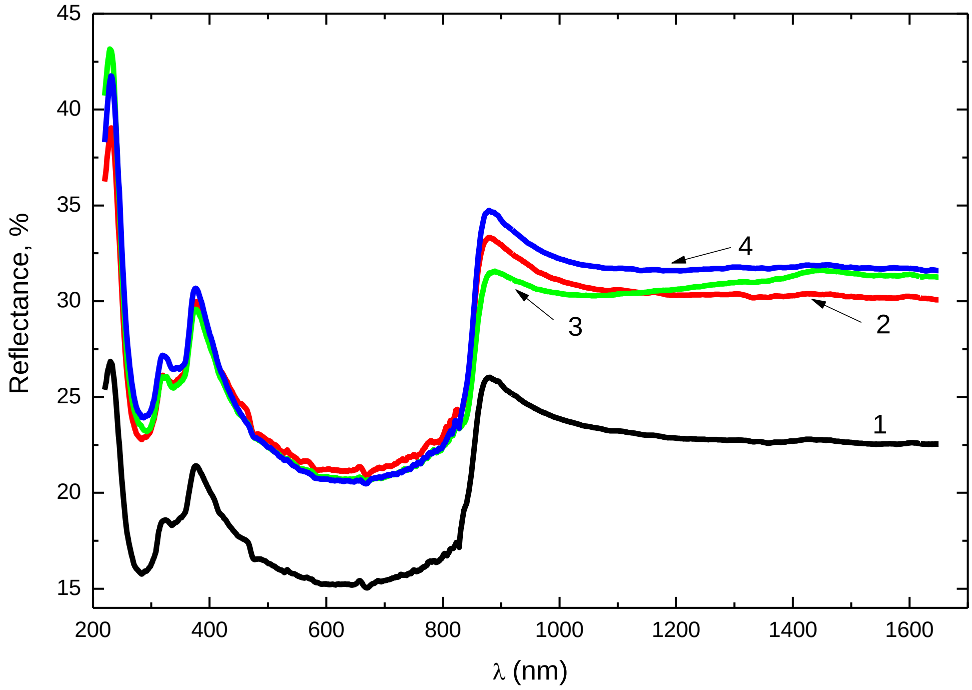

Fig. 3. Reflection spectra of single crystals *p*-CdTe (111): original sample is curve 1 and the samples are irradiated with energy of 66 mJ/cm^2; 108 mJ/cm^2, 164 mJ/cm^2 - curves 2-4 respectively.

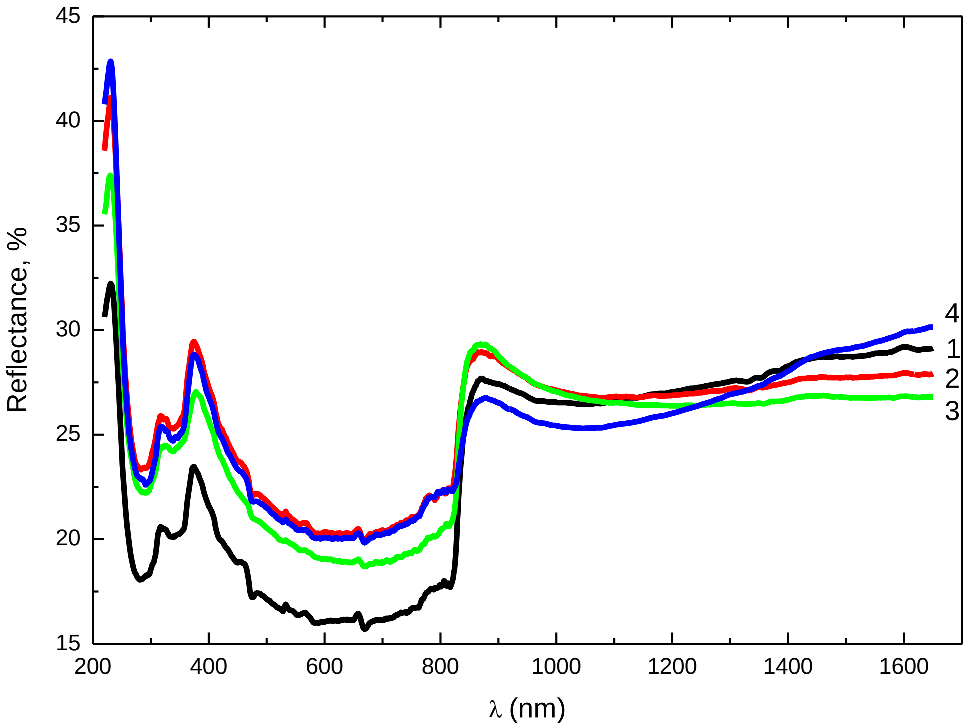

Fig. 4. Reflection spectra of solid solutions $Cd_{1-x}Zn_xTe$ (x = 0.1): original sample is curve 1 and the samples are irradiated with energy of 46.66 mJ/cm^2; 102.3 mJ/cm^2, 163.5 mJ/cm^2 - curves 2-4 respectively.

this paper.

The constructed optical absorption spectra $D = [1-(T+R)] = f(\lambda)$ of these materials are completely correlated with the optical transmission spectra $T = f(\lambda)$ and the reflection $R = f(\lambda)$. From the absorption spectra (Fig. 5, 6) of the material shows that the lower energies, i.e. at the energies of light (electromagnetic) waves E which is much lower than the fundamental optical transition energy E_0, absorption of single crystals *p*-CdTe (111) after laser treatment with an energy density of 66 mJ/cm^2 and 164 mJ/cm^2 becomes smaller compared to the original samples (Fig. 5 curves 1, 2, 4). In laser processing of single crystals *p*-CdTe (111) with an energy density of 108 mJ/cm^2, the absorption of the samples is significantly increased (Fig. 5 curve 3). For solid solutions of $Cd_{1-x}Zn_xTe$ (x = 0.1), the absorption of the samples is significantly increased by laser treatment with energy densities of 46.6 mJ/cm^2; 102.3 mJ/cm^2; 163.5 mJ/cm^2 compared to the original samples (Fig. 6, curves 1-4).

Based on the Heisenberg uncertainty principle for energies E and time t ($\Delta E \cdot \Delta t \geq \hbar$), the relaxation effects in light absorption by a crystal are described by the expansion parameter $\Delta E = \hbar / \tau$ (the broadening of the electronic transition E_0 is related to the free charge carrier life due their interaction with lattice vibrations, impurities, defects including surface character), where τ is the time of energy relaxation of the photo-generated steam.

According to the experimental data on the optical transmission and reflection spectra (Figs. 1-4) for single crystals p-CdTe (111) with specific resistance of (2 ÷ 5)·10^9 Ω·cm and solid solutions $Cd_{1-x}Zn_xTe$ (x = 0.1) with a specific resistance of (0.5 ÷ 3)·10^{10} Ω·cm the energy expansion of the optical spectra of these materials is 0.049 eV; 0.075 eV, respectively.

Energy relaxation time of photogenerated pairs τ for single crystals single crystals p-CdTe (111) and solid solutions $Cd_{1-x}Zn_xTe$ (x = 0.1) is equal to 1.343·10^{-14} s and

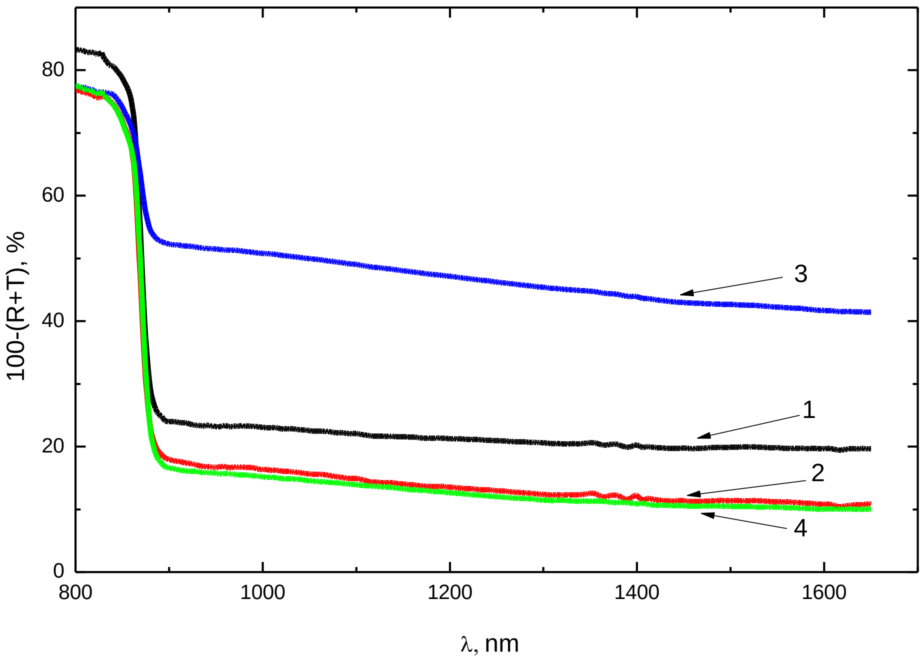

Fig. 5. Absorption spectra of single crystals p-CdTe (111): original sample is curve 1 and the samples are irradiated with energy of 66 mJ/cm^2; 108 mJ/cm^2, 164 mJ/cm^2 - curves 2-4 respectively.

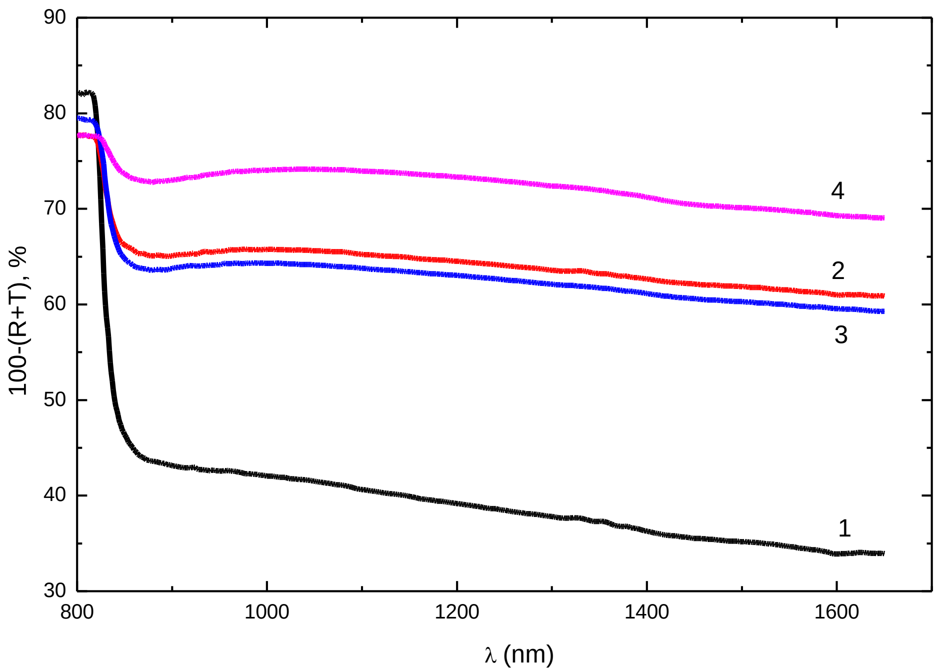

Fig. 6. Absorption spectra of solid solutions $Cd_{1-x}Zn_xTe$ (x = 0.1): original sample is curve 1 and the samples are irradiated with energy of 46.66 mJ/cm^2; 102.3 mJ/cm^2, 163.5 mJ/cm^2 - curves 2-4 respectively.

$0.878 \cdot 10^{-14}$ s respectively.

According to the literature data [7-9], the oxide coatings of the surfaces of the investigated materials are amorphous films, the thickness of which ranges from 0.5 to 0.7 nm. It should be noted that at the interface of the semiconductor-oxide there is a transition layer of oxide.

Conclusions

Experimental studies have shown that the main mechanism of influence of pulsed laser irradiation on the optical properties of thin surface layers of the investigated crystals is structural gettering, that is, the absorption due to the presence of sections of semiconductors that have a defective structure and have the ability to actively absorb defects. In single crystals *p*-CdTe (111) and solid solutions $Cd_{1-x}Zn_xTe$ (x = 0.1) the role of hetero play cadmium, tellurium, zinc and their complexes.

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Вплив лазерного опромінення на оптичні властивості високоомних кристалів CdTe та твердих розчинів $Cd_{1-x}Zn_xTe$

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В даній роботі проведено оптичні дослідження спектрів пропускання та відбивання монокристалів *p*-CdTe (111); твердих розчинів $Cd_{1-x}Zn_xTe$ (x = 0,1) в діапазоні $(0,2 - 1,7) \cdot 10^{-6}$ м до та після лазерного опромінення на довжині світлової хвилі λ = 532 нм в інтервалі енергій 66 - 164 мДж/см^2 для CdTe(111) та в інтервалі енергій 46,6 мДж/см^2-163,5 мДж/см^2 для $Cd_{1-x}Zn_xTe$ (x = 0,1). Встановлено, що основним механізмом впливу імпульсного лазерного опромінення на оптичні властивості тонких приповерхневих шарів досліджених кристалів є структурне гетерування, тобто поглинання, обумовлене наявністю ділянок напівпровідників що мають дефектну структуру і володіють здатністю активно поглинати точкові дефекти і зв’язувати домішки.

Ключові слова: CdTe, CdZnTe, пропускання, відбивання, поглинання, лазерне опромінення.