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Photoconductivity and photoluminescence features of γ-irradiated $GaS_{0.75}Se_{0.25}\langle Er\rangle$ single crystals

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Abstract. The effect of γ-radiation with $E = 1.3$ MeV energy and $D_\gamma = 10\ldots200$ krad dose on photoconductivity and photoluminescence features of $GaS_{0.75}Se_{0.25}\langle Er\rangle$ single crystals was studied. When analyzing the experimental data it was established that after doping with the rare-earth element erbium $N = 10^{18}\,\mathrm{cm}^{-3}$ and γ-radiation the photoconductivity value and the intensity of photoluminescence radiation increased in the investigated samples. A defect-formation model explaining the observed characteristics was proposed.

Keywords: photoconductivity, photoluminescence, intensity, γ-irradiation, single crystal.

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1. Introduction

Recently, it has been intensively studied the A^3B^6 semiconductors and their solid solutions activated by rare-earth elements. When doping these materials, rare-earth elements give them new photoconductive and luminescent properties, improves their radiation resistance [1, 2]. A^3B^6 compounds and their solid solutions are promising materials for semiconductor detectors of elementary particles. Interest to these compounds stems from the fact that they have a high photosensitivity to the visible, ultraviolet, X- and γ-rays [3 – 5].

The aim of this work is to study the γ-irradiation influence on the photovoltaic and photoluminescent properties of $GaS_{0.75}Se_{0.25}\langle Er\rangle$.

2. Experimental

The investigated $GaS_{0.75}Se_{0.25}\langle Er\rangle$ single crystals of $\rho \sim 10^9$ Ohm·cm resistivity at room temperature were grown using the Bridgman method. Doping with erbium was realized in the growing process. The erbium concentration in the sample equaled to $N = 10^{18}\,\mathrm{cm}^{-3}$. γ-irradiation of the samples with 1.3 MeV and $D_\gamma = 10\ldots200$ krad dose was performed using Co^{60} irradiation source at room temperature. Ohmic contacts were applied on the opposite surfaces of the crystal with a silver paste. The photoconductivity was measured using the stationary technique [6].

The photoluminescence spectra readings of the investigated samples were taken via SDA – 1 spectrometer. The spectrometer was composed of a double monochromator with replaceable diffraction lattices, illuminator with ДРШ-type lamp, condensor, energy detector and amplification-recording unit. A mercury-vapour high-pressure lamps ДРШ – 250 – 3 and ДРШ – 500m served for excitation of luminescence. The sample was placed into a holder and illuminated by high-power monochromatic beam selected with a light filter (λ = 337.1 nm) from the spectrum of the mercury-vapour lamp. ФЭУ – 39А and ФЭУ – 62 photoelectric multipliers served as energy detectors. The radiation curves were registered by КСП – 4 electron recording potentiometer.

3. Experimental results

The study of the photoelectric phenomena in $GaS_{0.75}Se_{0.25}\langle Er\rangle$ single crystals with various defects is interesting in the aspect of other considerations as well. The matter is that one of the main advantages of this semiconductor is as follows: with the change of composition the band-gap energy, concentration and mobility of free charge carriers, energy depth of impurity levels can be varied within a very wide range.

In Fig. 1, the spectral dependences of photoconductivity observed in the investigated samples before and after irradiation at 300 K are shown. The spectral region of $GaS_{0.75}Se_{0.25}\langle Er\rangle$ single crystals covers

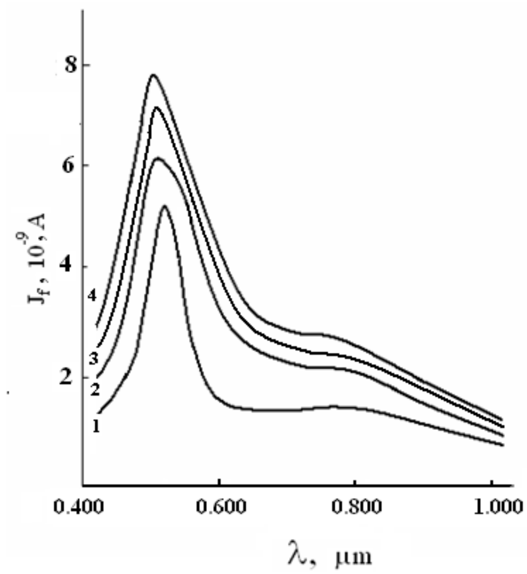

Fig. 1. Spectral dependences of photocurrent at 300 K before (1) and after irradiation with the following doses D_γ: 30 krad (2), 200 krad (3), 100 krad (4).

the wavelength region of 0.400 to 1.000 μm. In the photoconductivity spectrum for non-irradiated samples, two peaks with λ = 0.540 μm and 0.800 μm were revealed. After γ-irradiation, the photocurrent value increases over the whole spectral region, while the maxima of intrinsic and impurity peaks shift to shorter wavelengths. With growing the irradiation dose (above D_γ > 100 krad), the photosensitivity value decreases.

Fig. 2 shows the photoluminescence spectra of $GaS_{0.75}Se_{0.25}\langle Er\rangle$ single crystals at 77 K. It is clear from Fig. 2a that the spectral region of radiation for the non-irradiated sample begins from 0.460 μm and expands up to 0.600 μm. Maxima of the bands are located at 0.545 and 0.555 μm. After irradiation with D_γ = 30 krad, the radiation increases and observed in the photoluminescence spectrum are six distinct lines. Irradiation with the dose 100 krad leads to an increase in the intensity of 0.545 and 0.555 μm bands. Further irradiation with the dose D_γ = 200 krad (Fig. 2d) leads to a gradual decrease in the intensity of the peaks, and the spectrum takes the form like to that of non-irradiated samples.

4. Discussion

As known [7], Er enters into the lattice as an impurity in the course of doping the $GaS_{0.75}Se_{0.25}\langle Er\rangle$ single crystals, which replaces gallium atoms in the cationic sublattice of the crystal with generation of small donor centers. Evidently, the impurity maxima of photoconductivity (λ = 0.800 μm) are related with these centers, which are observed at room temperature in $GaS_{0.75}Se_{0.25}\langle Er\rangle$ single crystals. Besides, they are conditioned by photoexcitation of electrons with valence band at empty Er_{Ga} donor centers at room temperature, with a consequent thermo-ionization in the photoconductivity region.

Fast (*s*) and slow (*r*) centers play the main role in recombination processes in these crystals. In accord with [8], it can lead to much stronger changes in the concentration of local levels, as well as photosensitivity of *r*-centers in a defect-formation process during irradiation.

On the basis of the obtained experimental data, it is difficult to judge about the nature of new *r*-centers, but it can be assumed that these centers are responsible for defect complexes which include V_{Ga} and Er atom. Formation of these complexes during irradiation of

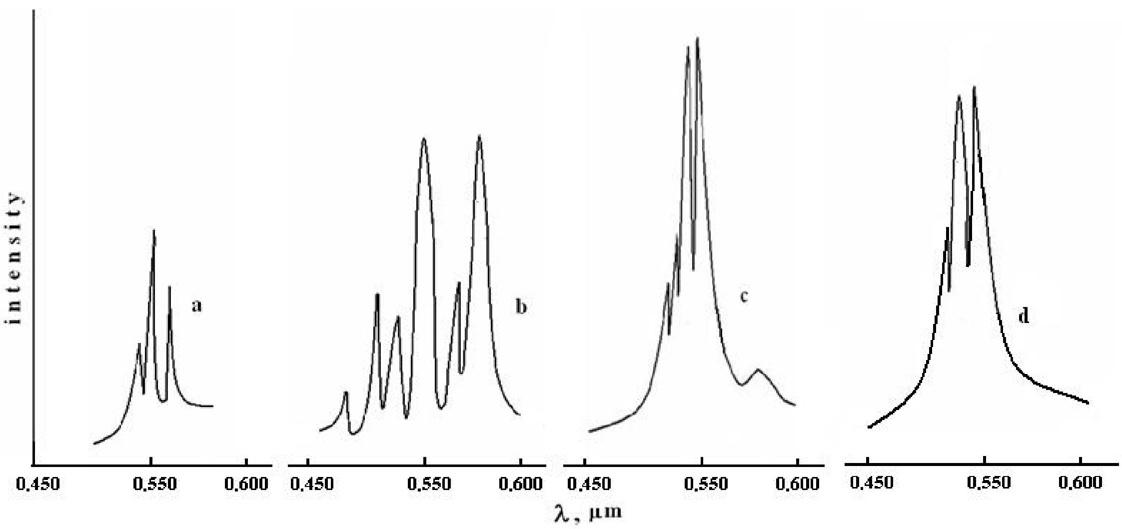

Fig. 2. Photoluminescence of $GaS_{0.75}Se_{0.25}\langle Er\rangle$ single crystals at 77 K before (a) and after irradiation with the following doses D_γ: 30 krad (b), 100 krad (c), and 200 krad (d).

$GaS_{0.75}Se_{0.25}$⟨Er⟩ single crystals is stimulated by high mobility of Er atoms and V_{Ga} appearing under irradiation.

The occurrence of new *r*-centers with the concentration after irradiation more than the concentration of V_{Ga} before irradiation in the sample results in photoconductivity and photoluminescence increase and typical photoconductivity decrease [9], as these centers, like others with slow recombination, are acceptors.

The decrease in photosensitivity of both bands in the γ-irradiated sample as well as luminescence at high doses ($D_\gamma > 100$ krad) is evidently related with several reasons. In the course of γ-irradiation, non-irradiated "fast" recombination centers are also observed together with the irradiated ones that accumulate and self-redistribute an essential part of the recombination flow of non-equilibrium carriers. Besides, with the rise in the concentration of radiation defects the screening effect of some defects is increased due to the other fields, which correspondingly leads to the change of capture cross-sections of carriers by recombination centers and probably to the rise of the role of radiationless transitions, reducing the quantum yield and photosensitivity of highly-irradiated samples [10].

5. Conclusion

It can be concluded that γ-irradiation of $GaS_{0.75}Se_{0.25}$⟨Er⟩ single crystals results in formation of small acceptor trapping levels of compensating deep donors which are sensitizing for *r*-recombination centers. As a consequence, photosensitivity and photoluminescence increase.

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