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Influence of γ-Irradiation on the Electrophysical Properties of in$_{1-X}$sm$_x$se Single Crystals

***A. A. Ismailov, *N. Z. Gasanov, **A. A. Ismailov, ***Z. M. Narzullaeva**

**Institute of Physics of the National Academy of Sciences of Azerbaijan, Baku, Azerbaijan, AZ-1143, 131 G. Javid Ave.*
***Azerbaijan Technical University, Baku-143, 25 H.Javid Avenue*
****Bukhara Medical Institute named after Abu Ali ibn Sino, 200118 Bukhara, Uzbekistan*

ABSTRACT: It has been found that in γ-irradiated single crystals of $In_{1-x}Sm_xSe$ solid solutions, the region of intrinsic conduction appears at a temperature of ~450K. Thermo – e.m.f. with increasing temperature from room temperature to ~ 450K it increases, and at T > 450K it decreases, which is due to a change in the concentration of charge carriers.

KEYWORDS: γ-irradiated, solid solutions, own conductivity, thermo – e.m.f., charge carriers.

Introduction: Known semiconductor detectors of hard radiation based on Ge and Si [1], as well as semiconductor compounds of the $A^{II}B^{VI}$ type (CdS, CdSe, etc.) [2-4], GaAs and Sb_2S_3 [5-7], although they have a relatively high sensitivity, but detectors based on these materials are characterized by a significant inertia. In this regard, representatives of non-full-valent semiconductor compounds of the $A^{III}B^{VI}$ [8] type compare favorably. GaSe and InSe single crystals exhibit significant sensitivity to hard radiation and are of great interest for the development of detectors of such radiation [9] based on them. The possibilities of this class of semiconductors in terms of X-ray and gamma dosimetry have not yet been fully disclosed, so there is a need for additional studies ofthe interaction of crystals of these compounds with X-ray and gamma radiation [10].

Research methodology: Crystals of solid solutions $In_{1-x}Sm_xSe$ (x=0; 0.03; 0.05; 0.07 mol%) were synthesized by fusing the corresponding components, taken in a stoichiometric ratio, in graphitized quartz ampoules, evacuated to a residual pressure of $1,3 \cdot 10^{-2}$ Pa, in a two-temperature furnace using vibratory mixing [7]. For the synthesis the following were used: indium - In 000, selenium grade B-3 and samarium grade M-1. High-quality $In_{1-x}Sm_xSe$ single crystals are grown from synthesized ingots by a modified Bridgman method.

To study the electrical properties the samples cleaved from single-crystal blocks, after appropriate processing, had dimensions of 5x4x3 mm^3 and were oriented along the crystallographic axes. Silver

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paste was used as a contact material. Irradiation of samples with γ-quanta with an energy of 1,25 MeV and a flux density of $1,4 \cdot 10^{11}$ quantum/s·cm^2 was carried out at room temperature on the CRChIN-20000 installation (continuous radiation chemical installation) from a Co^{60} source.

Results and discussion: In the range of 300–800 K, the temperature dependences of the electrical conductivity and thermal - e.m.f. were studied in $In_{1-x}Sm_xSe$ single crystals before and after gamma irradiation.

Irradiation of undoped InSe samples with a resistivity of 10^4 Ω·cm by gamma rays leads to a significant change in electrical characteristics (γ-quanta with a dose of $2,58 \cdot 10^2$ C/kg). Due to the emerging radiation defects, the concentration of local levels increases and the band gap decreases. This leads to an increase in electrical conductivity by 70–80%. Doping of InSe crystals with samarium also increases their electrical conductivity.

The experimentally obtained temperature dependence of the electrical conductivity is shown in Fig. 1 on a semilogarithmic scale. This shows that as the temperature increases from 300 K to 450 – 500 K, the electrical conductivity sharply decreases according to an exponential law, and after a temperature of 450 K up to 800 K, the gradient of the temperature dependence of the electrical conductivity decreases. In the studied temperature range, electrical conductivity obeys the exponential law $\sigma = \sigma_o e^{-\frac{\Delta E}{}}$.

The study of thermos – e.m.f. (Fig. 2) it was found that both non-irradiated and γ - irradiated $In_{1-x}Sm_xSe$ crystals have n-type conductivity. Thermo – e.m.f. γ -irradiated $In_{1-x}Sm_xSe$ crystals, as well as non-irradiated ones, increases up to 450 K, and after this temperature decreases.

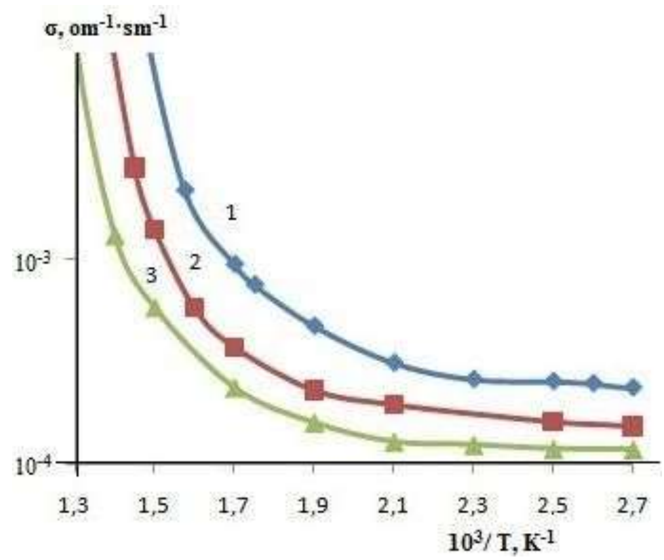

Fig.1. Temperature dependence of the electrical conductivity of single crystals of solid solutions $In_{1-x}Sm_xSe$: 1-x = 0.07; 2-x = 0.05; 3-x = 0.03.

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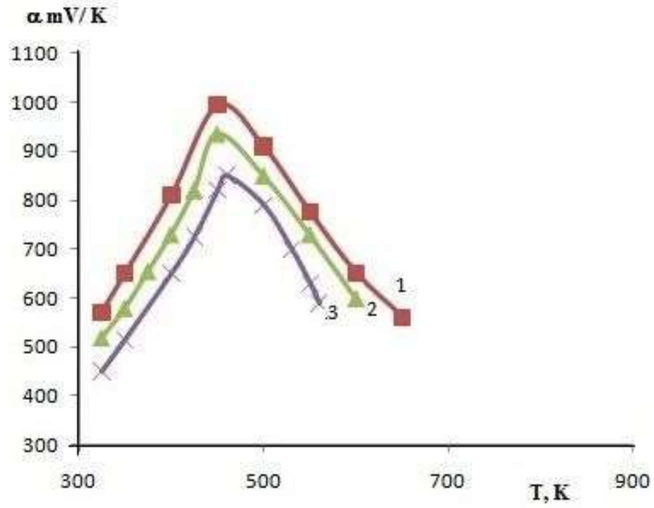

Fig.2. Temperature dependence of thermos – e.m.f. single crystals of solid solutions $In_{1-x}Sm_xSe$: 1-x = 0.03; 2-x = 0.05; 3-x = 0.07.

Thermo - e.m.f. semiconductors with one type of carriers is determined by the Pisarenko formula:

$$\alpha = \pm \frac{k}{e}\left[2,5 + r + \ln \frac{2(2\pi m^{*} kT)^{3/2}}{h^{2} n}\right],$$

where k - is Boltzmann's constant, r - is an index equal to 1 for nonpolar optical scattering, m*- is the effective mass of current carriers, T - is the absolute temperature, h - is Planck's constant, n - is the carrier concentration. From this formula it follows that the change in thermos – e.m.f. mainly determined by the change in the concentration of current carriers.

Conclusion: By comparing the electrical properties of non-irradiated [11] and irradiated $In_{1-x}Sm_xSe$ single crystals with gamma quanta, it is shown that after irradiation, the electrical conductivity and the thermal e.m.f. peak increase increases by about 21%. It has also been established that in γ - irradiated $In_{1-x}Sm_xSe$ crystals, the intrinsic conduction region appears at ~450K.

Thermo – e.m.f. single crystals under study from room temperature to ~450 K increases, and above a temperature of 450 K it decreases, which is due to the temperature change in the concentration and effective mass of current carriers.

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