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INFLUENCE OF DOPING BY Zn (0.01 at% Zn) ON CONDUCTIVITY OF InGaSb EQUIMOLAR COMPOSITION

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The investigations of Hall coefficient and thermo-e.m.f. in $In_{0,5}Ga_{0,5}Sb$ doped by Zn (up to 0.01 at% Zn) in temperature interval T=100-500 K are carried out. It is revealed that the highly mobile electrons make the significant contribution into Hall coefficient in equimolar composition at T>350 K. It is established that the contribution of highly mobile electrons is suppressed in $In_{0,5}Ga_{0,5}Sb$ equimolar composition with increase of Zn content and the conductivity has the hole character. The effective mass of holes ($m^*=0.36m_0$) is evaluated by data of thermo-e.m.f.

Keywords: $In_{0,5}Ga_{0,5}Sb$, Hall coefficient, thermo-e.m.f.
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INTRODUCTION

InSb-GaSb solid solutions pay attention of investigators by their well solubility of initial binary compounds up to $In_{0,5}Ga_{0,5}Sb$ equimolar composition. The low values of thermal conduction and carrier effective mass [1 – 3] in this system allow us to recommend this object for the formation of different recorders: thermal receptor, Hall probes and etc. [4–6].

The doping of $In_{0,5}Ga_{0,5}Sb$ equimolar composition allows us to vary the crystal parameters.

The investigation results of the influence of Zn atom introduction (0.001 at% Zn and 0.01 at % Zn) in initial matrix of equimolar composition on concentration and thermo-e.m.f. S are presented in this work. This allows us to predict the direction of increasing of recorder characteristics.

EXPERIMENTAL PART

The large-block polycrystalline samples are obtained by the method of direct alloying of initial materials In(99.000%), Ga(99.999%) Sb (0000) and Zn (pure for synthesis).

The ampoule heating with the given substances is carried out up to 700^0C. The zone leveling with the consistency of molten zone passage, width 3-4 mm with velocity 5.2 and 1 mm/h at temperature 700^0C is carried out. The samples in the form of parallelepipeds $12\times5.2\times2.5mm^3$ are cut from obtained ingots. The measurements of Hall coefficient R and thermo-e.m.f. S are carried out by four-probe potentiometric method in temperature interval T=100-500 K.

The temperature dependences of Hall coefficient R for equimolar $In_{0,5}Ga_{0,5}Sb$ (1) and doping of Zn: $In_{0,5}Ga_{0,5}Sb$ +0.001at% Zn(2), $In_{0,5}Ga_{0,5}Sb$ +0.01at% Zn (3) are shown in Fig.1.

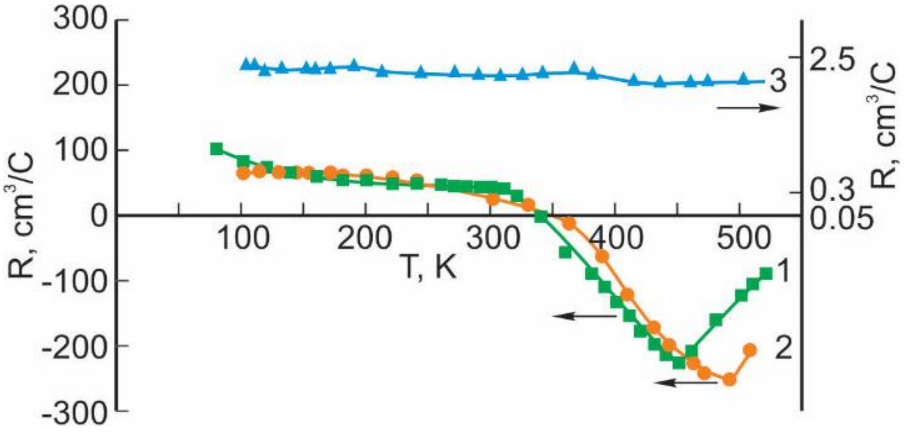

Fig. 1. Temperature dependences of Hall coefficients in $In_{0,5}Ga_{0,5}Sb$ (1), $In_{0,5}Ga_{0,5}Sb$ +0.001aт% Zn (2), $In_{0,5}Ga_{0,5}Sb$ +0.01aт%Zn (3).

As it is seen Hall coefficient in initial equimolar composition (sample 1) in temperature interval T=100-300 K weakly changes with temperature, further, at T≈350K changes the sign on the negative one. Further, the temperature dependence R(T) passes through the maximum at T≈440K. Such behavior can be explained by the following way. At T<300 K the conductivity is carried out by the holes. The ionization of deep donor is carried at T>300K by that the sign inversion R(T) and the further increase of Hall coefficient is caused. The passing of R(T) dependence through the maximum is caused by competitive contribution in the conductivity of the holes and electrons and further, by predominating of electron conductivity.

The character of temperature dependence R(T) practically doesn't change at introduction 0.001a%Zn (sample 2). The further increase of Zn (0.001at%Zn-sample 3) content leads to the decrease on approximately value order of Hall coefficient. As it is seen R>0 for this composition in whole investigated interval. One can predict that increase of Zn atom content leads to significant increase of active impurity centers and moreover, to significant compensation of electron contribution into Hall effect.

The temperature dependences of S thermo-e.m.f. shown in Fig.2 is the proof of these preliminary conclusions.

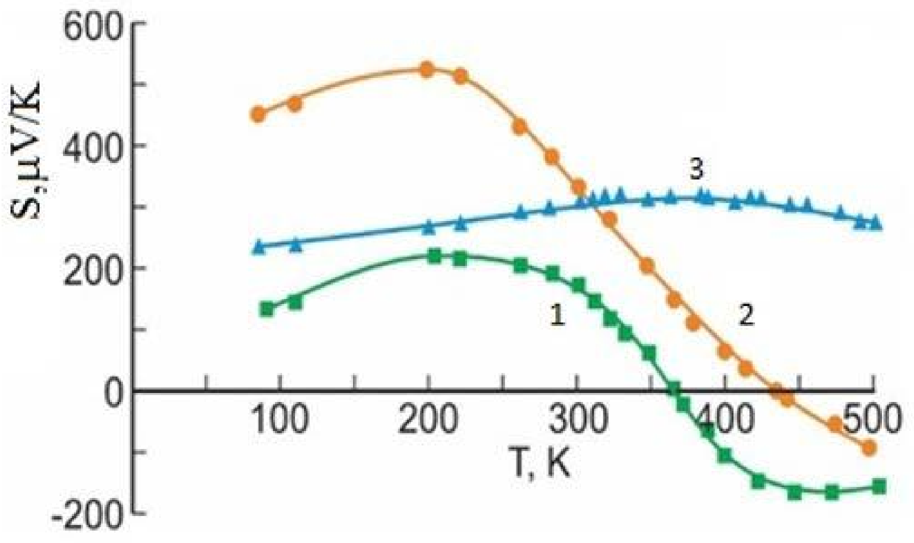

Fig. 2. Temperature dependences of thermo-e.m.f. of $In_{0,5}Ga_{0,5}Sb$ (1), $In_{0,5}Ga_{0,5}Sb$ +0.001at% Zn (2), $In_{0,5}Ga_{0,5}Sb$ +0.01at%Zn (3).

The dependence of thermo-e.m.f. on temperature S(T) in equimolar composition $In_{0,5}Ga_{0,5}Sb$ (sample 1) is like the dependence of Hall coefficient R(T): up to T≤360 K, thermo-e.m.f. is positive one; further the inversion of α_0 sign on negative one and later increase of thermo-e.m.f. S with temperature takes place. The small increase of S thermo-e.m.f. in interval from 100K up to 200K is caused by mixed character of scattering carriers on impurity ions and acoustic phonons. The decrease of S thermo-e.m.f. value in temperature interval from 200K up to sign inversion point is caused by the beginning of the ionization of donor centers and increase of the contribution of more mobile electrons in total thermo-e.m.f. S. This also explains S(T) increase in the region where S<0. The doping of the initial composition 0.001 at % Zn (sample 2) leads to the thermo-e.m.f. S more than in 2 times, the inversion point of thermo-e.m.f. S sign shifts to the side of more high temperatures (T≈430K). Such behavior of S(T) for $In_{0,5}Ga_{0,5}Sb$+0.001at% Zn sample evidences on the fact that the doping by Zn leads to the increase of acceptor center number. The temperature dependence of thermo-e.m.f. S(T) in $In_{0,5}Ga_{0,5}Sb$+0.01at% Zn (sample 3) evidences on total suppression of electron contribution in thermo-e.m.f. S.

DISCUSSION

The weak dependence of Hall coefficient R(T) on temperature in temperature interval 100 – 300K in $In_{0,5}Ga_{0,5}Sb$ and $In_{0,5}Ga_{0,5}Sb$ +0.001at% Zn samples (see Fig.1) allows us to evaluate the hole concentration.

№ of the sample	Composition	p ,cm^{-3}
1	$In_{0,5}Ga_{0,5}Sb$	$4.4\cdot10^{16}$
2	$In_{0,5}Ga_{0,5}Sb$ +0.001at% Zn	$3\cdot10^{17}$
3	$In_{0,5}Ga_{0,5}Sb$ +0.01at% Zn	$2.9\cdot10^{18}$

The same evaluation of hole concentration by the data of temperature dependence of Hall coefficient R(T) in the whole investigated temperature interval 100 – 500K (where R on T practically doesn't depend) gives the value $\rho=2.9\cdot10^{18}$ cm $^{-3}$ (see Fig. 1). The increase of hole concentration with increase of Zn content evidences on the fact that the doping of Zn atoms leads to formation of additional electroactive centers.

If we take under the consideration the fact that hole scattering on acoustic phonons dominates in temperature interval 200 – 300K, so by the known ratio [6]:

$$S = \frac{k_0}{e}\left[\frac{F_{r+2(\eta^*)}}{F_{r+1(\eta^*)}} - \eta^*\right], \qquad (1)$$

(where $F_r(\eta*)$ is Fermi one-parameter integral, $\eta* = \eta/k_0T$ is given chemical potential, r is parameter of scattering mechanism of charge carriers, at scattering on acoustic phonons r=0) one can estimate the given chemical potential.

One can estimate the hole effective mass by the data of concentration and given chemical potential by the formula [7]:

$$\rho = \frac{(2m_p k_0\, T)}{3\pi^2\hbar^3} F_{3/2}\ (\eta^*) \quad , \qquad (2)$$

The value of hole effective masses are practically similar and equal to $m_p^* = 0.36m_0$ for the investigated compositions.

CONCLUSION

Thus, the analysis of the obtained results shows that the introduction of Zn up to 0.01at % in $In_{0,5}Ga_{0,5}Sb$ equimolar composition leads to the formation of impurity centers of acceptor type, as a result of which the conductivity has the pure hole character. The effective mass of the holes $m_p^* = 0.36m_0$ is estimated on the base of data of thermo-e.m.f.

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