# THERMAL CONDUCTIVITY AND THERMAL EMF OF MATERIALS FOR THERMAL ENERGY CONVERTERS

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**ABSTRACT**

There are studied electrophysical characteristics and heat conductivity of solid solutions

$Er_x Sn_{1-x} Se$ with concentration $0,0 \le X \le 2,5 am\%$. The re is determined that at replacement of tin on erbium a part of double charged centers of tin vacancy is recombined by erbium and at concentration ≈ 0,4 *am%Er-a p* sign is changed on *n*-type of heat conductivity. There is estimated activation energy of charge carrier and there is determined the width of band gaps in the alloy of $Er_x Sn_{1-x} Se$ system. There is discovered dispersion mechanism which in *T=77-350K* occurs mainly upon ions of charged centers, and dispersion mechanism becomes visibly stronger upon acoustical phonons by increase of temperature.

**Keywords:** electrophysical characteristics, dispersion, acoustical phonons, temperature.

## I. INTRODUCTION

There is many literary data about synthesis and physical-chemical characteristics of solid solutions and compounds on the basis of monochalcogenids with participation of rare earth elements, especially on the basis of *SnSe*[1,3]. Selenide of tin *SnSe* is one-side phase with plenty of chalcagen (selenide) versus stoichiometry, and therefore, has *p*- type of heat conductivity [1,2]. At the same time, there is reported that predominant defects in crystals *SnSe* are double ionized vacancies of tin [2,3]. The aim of our work, studying of influence of solid solutions $Er_x Sn_{1-x} Se$ on defects and electrophysical characteristics at replacement of tin on trivalent rare earth metal (*Er*) are of interest. After all, rare earth metals, particularly trivalent erbium is electrically active by its specific characteristics and it can be supposed that it is possible to control concentration of defects as well as to discover nature and mechanism of deficiency conversion by using of this metal ($E_r^{3+}$).

In the present work there is studied heat conductivity ($\sigma$), thermoelectromotive (α), Hall coefficient – $R$, heat conductivity (χ) and calculated concentration ($p(n)$) and mobility of charge carrier against content of erbium (*Er*) in solid solution $Er_x Sn_{1-x} Se$ $(0,0 \le X \le 2,5\%)$. Researches are carried out and analyzed during interval of temperatures : $T=77 \div 750K$.

## II. EXPERIMENTAL TECHNIQUE

Samples were obtained by direct alloying of initial components in vacuum-degassed quartz vessels. Initial components were especially clean initial components. Homogenized annealing of monophase samples obtained was being made in sphere of spectral clean argon at 800K during five days. Contents of synthesized samples meet value *x=0,00; 0,10; 0,50; 1,00; 1,50; 2,50am%Er.*

The studied samples had *p* and *n*-types of heat conductivity. Samples in the size of $(2x4)16mm^3$ were cut out from bars of crystals on spark cutting device.

Thermoelectromotive (α) and heat conductivity (χ) were measured by stationary method by system described in [4], heat conductivity – ($\sigma$) and Hall coefficient ($R$) were measured at direct current and magnetostaticfield of electromagnet [5]. Errors of measure of thermoelectromotive and heat conductivity was less than 6,5%, and Hall coefficient and electroconductivity ≈ 2,7%.

## III. RESULTS AND DISCUSSIONS CONCERNING THEM

Replacement of atom of tin (*Sn*) on atoms of erbium (*Er*) in different concentrations change energy spectrum of electrons in *SnSe* creating deep and resonant position [6] and distort lattice of solid solutions (table 1).

It is seen from table 1 that in solid solution along with increase of concentration *Er* parameters of lattice keeping orthorhombic structure is being increased little by little. Observable change of parameters of lattice of studied samples $Er_x Sn_{1-x} Se$ can be related to various ionized radiuses of replaceable ($E_r^{3+}$ - $1,18A^0$) and irreplaceable ($S_n^{2+}$ - $1,02A^0$) atoms distributed statically in octahedral vacuum under lattice. In other words, in solid solutions there is occurred not only replacement of atom *Sn* on atoms *Er* but also partial fulfill of double charged vacancy centers by tin.

*T=300K* Table 1

| Content *am%* / Parameter of lattice | *x=0,00* | *x=0,25* | *x=0,50* | *x=1,00* | *x=2,5* |
|---|---|---|---|---|---|
| a | 4,4594 | 4,4645 | 4,4799 | 4,5013 | |
| b | 4,1704 | 4,1734 | 4,1734 | 4,1749 | |

| | | | | | |
|---|---|---|---|---|---|
| c | 11,4784 | 11,4832 | 11,4953 | 11,5104 | |
| Thermal width of band gap *Eg(eV)* | 0,96 | 0,88 | 0,67 | 0,50 | 0,37 |

Dependence of thermoelectromotive (α) is represented on the figure 1. Heat conductivity – ( $\sigma$ ); concentration of charge carrier, *p(n).* As it is seen from the figure, meaning of coefficient of thermoelectromotive (α) (curve 1), heat conductivity ( $\sigma$ ) (curve 2) and concentration of charge carrier (curve 3) decrease rarely by increase of concentration of erbium (*Er*) and at *x≥0,4 am%* changes sign from *p* to *n*-type of heat conductivity. During further increase of content of *Er*, in solid solutions $Er_x Sn_{1-x} Se$, there is observed gradual increase of $\sigma$ and concentration of charge carrier in *n*-type of heat conductivity.

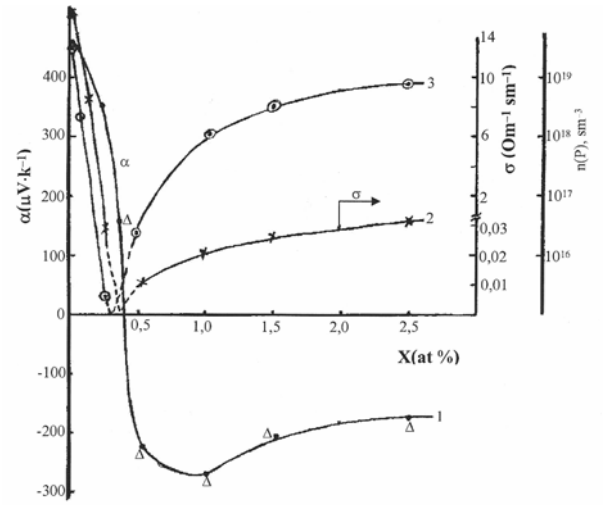


Fig. 1. Dependence of electrophysical characteristics on content of erbium in solid solutions $Er_x Sn_{1-x} Se$ at 300K.
1. α- thermoelectromotive; 2 – $\sigma$ electroconductivity; 3 – p(n) concentration of charge carrier.

On the figure 2, there are presented experimental data of heat conductivity (χ) and activation energy of charge carrier calculated by temperature dependence of heat conductivity ( $\sigma$ ) for studied samples. It is seen from the figure that activation energy of charge carrier (ΔEg) decrease gradually from $\Delta Eg_1 = 0,28$ ***eV*** to $\Delta Eg_2 \approx 0,51$ ***eV*** (curve 2) by increase of *Er.* Heat conductivity in solid solution, along with increase of erbium, at first, decreases to 23% at small concentration (*0,0≤x≤0,05*), and during further increase of content of *Er* the meaning of χ increases up to $16,0 \cdot 10^3$ *W/smK (*on 12,5%*)*(curve 1). Electronic part of heat conductivity in the studied samples is very small and doesn't exceed 0,067% of total heat conductivity of samples. By neglecting of electric constituent heat conductivity, we have $\chi_{total} \approx \chi_l$ [7].

Analysis has shown that by increase of percentage of *Er*, in compound, the width of band gap decreases and heat conductivity increases (table 1).

Such change of heat conductivity by increase of erbium in solid solutions and change of sign from *p* on *n*-type of heat conductivity as well as change of α(x) and $\sigma$ (x) give ground to think that the studied compounds have compensated semiconducting materials. At small concentration of *Er* (up to *0,5am*%), decreasing of χ is probably connected with anharmonicity of phonon flows which arise between additionally scattering center and defects. Along with increase of concentration of erbium by account of recombination of a part of vacancy places, anharmonicity of phonon flows becomes looser and heat conductivity of samples becomes better.

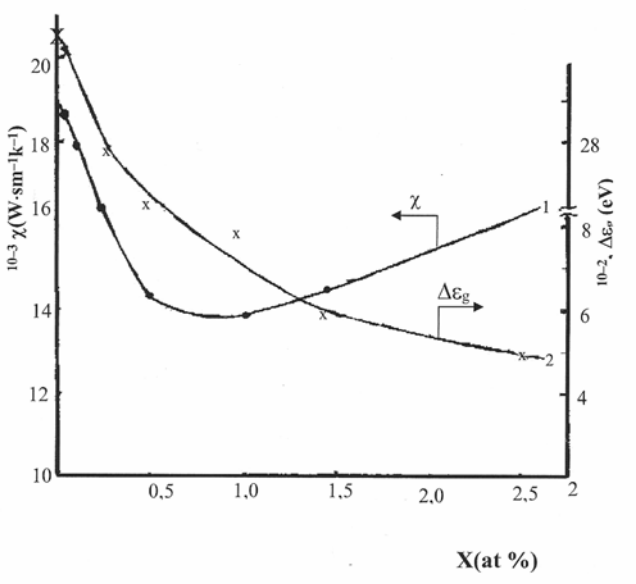


Fig. 2. Dependence of heat conductivity and activation energy of charge carrier on content of erbium in solid solutions $Er_x Sn_{1-x} Se$ at 300K.
1. æ – heat conductivity; 2. ΔEg – activation energy of charge carrier

Hall mobility of charge carrier of samples was defined on the basis of temperature dependence $\sigma$ (*T*) and Hall coefficient there was determined that in the interval of temperatures *T=77-350K* Hall coefficient changes by the rule $u \approx T^{1,27}$, and if T>*350K* by $u \approx T^{0,75}$ . Such change of Hall mobility gives grounds to suppose that before temperature of *T≤350K* dispersion mechanism of charge carrier occurs mainly in charged ionic centers, and over (*T>350K*) dispersion mechanism is visibly decreased on acoustical phonons also [7].

## IV.CONCLUSIONS

1) There is discovered that solid solutions obtained on the basis of $Er_x Sn_{1-x} Se$ are compensated semiconducting materials with mixed type of heat conductivity. At *x≈0,4% Er* changes sign *p* on *n*-type of conductivity.

1) 2) In solid solutions $Er_x Sn_{1-x} Se$ at replacement of *Sn* atom on *Er* atoms there is occurred partial recombination of double charged vacant centers of tin and at the same time atoms of erbium play a part of cleaners.

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