



Thermogenerators on the Basis of PbSe-TbSe Compounds

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Abstract

In this work a part of the state diagram of PbSe-TbSe system on the PbSe side has been constructed. Solid solutions based on lead monoselenide in the region of 0-8 mol% have been obtained in the system. Some electrophysical properties (thermo-e.d.s., electrical conductivity and thermal conductivity) of the obtained alloys at the temperature range of 300-700 K were investigated and the thermoelectric goodness of fit (Z , ZT), efficiency δ and power factor P were determined. The occurrence of high thermoelectric efficiency in the samples of composition $Tb_{0,05}Pb_{0,95}Se$ was found.

Keywords: Solid Solutions, Electrical Conductivity, Power Factor, Thermo-E.D.S., Thermal Conductivity, Thermoelectric Goodness, Efficiency.

INTRODUCTION

Semiconductor compounds of $A_{IV}B_{VI}$ type are considered as promising materials for applications in various fields of electronics such as thermoelectronic cells, solar cells, memory cells and others, or have already found their application. The fundamental characteristics of these compounds, such as narrow forbidden zone, high dielectric constant, relatively high radiation stability, high value of charge carrier mobility, predominance of ionic bonding, increase the possibility of their application [1, 2].

Doping with donor and acceptor impurities is widely used to study the energy spectrum of the conduction band bottom and valence band ceiling, the dispersion law, and the mechanism of charge carrier scattering in semiconductor compounds and their solid alloys. By doping, filling electron or hole states, it is possible to change the location of the Fermi level, and thus greatly simplify the calculations of zone parameters.

From this point of view, doping of binary compound PbSe of $A_{IV}B_{VI}$ type with rare earth elements or obtaining of solid solutions of small concentrations and comprehensive study of their physical properties is of interest. Obtained substances with participation of rare earth elements (REE) are widely used in the manufacture of various types of energy converters and thermistors resistant to radiation, pressure and humidity. The obtained materials with participation of REE, which have the transition 4f-5d-6s, due to the ease of complete filling of the 4f level of electronic structure, and the emergence of variable valence due to the movement of

electrons at the 4f level in the atoms, are interesting objects of study. From this point of view, melts and compounds based on the participation of REE provide an opportunity to obtaining new promising materials having the required physical properties, which is important for their research [3, 4].

EXPERIMENTAL METHODOLOGY

Alloys of the PbSe-TbSe system were synthesized from the initial elements in quartz ampoules evacuated to 0.1333 Pa. Synthesis was carried out in two stages: initially ampoules with the substance were heated at a rate of 4-5 deg/min. to the melting point of selenium and kept at this temperature for 3-4 hours, after which the temperature was increased to 950-1000°C, depending on the composition, and kept for 8-9 hours. In the synthesis of ternary alloys of the PbSe-TbSe system, elements of special purity were used as initial components.

Synthesized samples for complex physicochemical analysis and electrophysical studies were subjected to annealing for 100-140 hours. Homogenizing annealing of the obtained single-phase samples was carried out in the environment of spectrally pure argon at 800 K. After annealing, samples with dimensions of 2 x 4 x 18mm were cut out of crystal ingots on an electrospark machine.

The interaction in the PbSe-TbSe system was studied by differential thermal analysis (DTA), X-ray diffraction (XRD), microstructural analysis (MSA), as well as by microhardness measurement and density determination. XRD was carried out on an XRD instrument model D-2 PHSER using CuK α -radiation Ni-filter.

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Thermo-EDS was measured by the steady-state method according to the method described in [5]. Electrical conductivity was measured at constant current and constant magnetic field of the electromagnet [6]. Thermal conductivity was measured by the absolutely stationary method according to the method described in [7]. The measurements were carried out in the temperature range 300÷750K.

EXPERIMENTAL RESULTS AND THEIR DISCUSSION

In this work, a part of the state diagram of the PbSe-TbSe system on the PbSe side has been constructed. Solid solutions based on lead monoselenide in the region of 0-8 mol% have been obtained in the system. Some electrophysical properties of the obtained alloys of the system have been investigated by the compensation method in the absolutely

Table (T=300 K)

Sample composition	σ	S	χ	$Z \cdot 10^{-3}$	Z	δ	P
$x=0.0$	410	263	19.2	1.5	0.45	1.2	2.83
$x=0.005$	438	233	16.7	1.4	0.42	1.3	2.38
$x=0.01$	487	234	15.6	1.7	0.51	1.4	2.66
$x=0.05$	720	230	14.2	2.6	0.78	1.9	3.88
$x=0.075$	397	236	14.3	1.6	0.48	1.4	2.2

Studies show that the alloy systems $(PbSe)_{1-x}(TbSe)_x$ at low concentrations of TbSe, have p-type conductivity. With an increase in the amount of TbSe in the composition, in small concentrations, the Hall coefficient, specific electrical conductivity and mobility of charge carriers increases, and thermal conductivity monotonically decreases. Such dynamics of change in kinetic coefficients is the reason for monotonically increasing thermoelectric parameters such as goodness of fit, efficiency and power factor. Therefore, it can be expected that in these alloy systems, at a certain composition, the thermoelectric efficiency reaches values of practical interest in the corresponding temperature intervals. The analysis of the table shows that in the obtained alloy systems PbSe-TbSe, with the participation of Tb on the basis of PbSe, the thermoelectric efficiency depending on the ratio of components has different values. The analysis of thermoelectric efficiency shows that for the sample of composition $x=0.05$ mol% TbSe this parameter is the highest, reaching the value $Z=2.6 \cdot 10^{-3} K^{-1}$ at room temperature.

This value of thermoelectric goodness of fit is close to the used and promising materials. Therefore, the study of the temperature dependence of kinetic parameters and thermoelectric goodness of $Tb_{0.05}Pb_{0.95}Se$ alloys aroused interest, and the studies were continued by experiments in the temperature range $T=300-700$ K.

It is known that materials with thermoelectric properties that fulfill the condition $zT \approx 1$, depending on the application, are considered good thermoelectric materials. As is known, the thermoelectricity (S) and electrical conductivity (s) of a material depend on the properties of the electron and

stationary regime in the temperature range of 300-700 K. The obtained values were analyzed and general results were determined. First of all, the kinetic parameters of these samples at room temperature were calculated and based on these values the effect of thermoelectric goodness of fit (Z, ZT), efficiency $\delta = \frac{1}{S} \frac{ZT}{1+ZT}$ and power factor $P=\sigma \times S^2$ of the samples were determined. According to the theory of energy application, thermoelectric phenomena are characterized by values determined on the basis of the formula of goodness of fit $Z = \frac{S^2 \sigma}{\chi}$ of thermoelement material [8, 9]. Where S is the thermal-e.d.s. coefficient of the material, σ is the specific electrical conductivity, χ is the thermal conductivity.

The calculated kinetic coefficients and thermoelectric parameters for PbSe-TbSe alloys of different compositions are given in the table.

therefore, combining them can be written as a power factor $P=S \times S^2$. For efficient thermal materials, the power factor should be large and the thermal conductivity relatively small. For semiconductor crystals, the thermal conductivity factor, has mainly lattice and electronic components ($\chi_{tot} = \chi_{ph} + \chi_{el}$). Therefore, to increase the maximum of the thermoelectric criterion ($Z = \frac{S^2 \sigma}{\chi}$), for the smallest value of the total thermal conductivity, the fraction of electronic thermal conductivity should be as large as possible [8].

Figures 1 and 2 show the temperature dependences of thermo-e.d.s. and specific electrical conductivity of samples of composition $Tb_{0.05}Pb_{0.95}Se$. As can be seen from the graph, the value of thermo-e.d.s. monotonically increases from 210 $\mu V/K$ to 280 $\mu V/K$ in the temperature range $T=300-440$ K. At the subsequent increase of temperature, the value of thermo-e.d.s. passing through the maximum, decreases (Fig. 1, curve 1).

In the studied samples in the temperature range $T=300-420$ K a weak increase in electrical conductivity is observed. This area is the area of impurity conductivity of electrical conductivity, arising as a result of thermal excitation of the transition of charge carriers, from the conduction zone from the localized level, near the Fermi level, to the delocalized level. In the temperature range $420 K < T < 540$ K the electrical conductivity decreases. In the region of impurity reduction almost all impurities are ionized and the concentration of charge carriers does not depend on temperature, the electrical conductivity of charge carriers changes mainly due to the dependence of mobility on temperature. Passes through a weak maximum at 560 K and intensively increases with increasing temperature in the region of intrinsic

conductivity (Figure 1, curve 2). In this region of conductivity, having mainly energy $E > E_g$, occurs as a result of the transition of charge carriers from the valence zone to the conduction zone. This transition mechanism is explained by the weak dependence of the drift mobility on temperature. Therefore, such a strong increase in conductivity can only be explained by an increase in the concentration of charge carriers. The temperature dependence of thermal conductivity of the sample $Tb_{0,05}Pb_{0,95}Se$ is similar to the temperature dependence of specific electrical conductivity. Due to

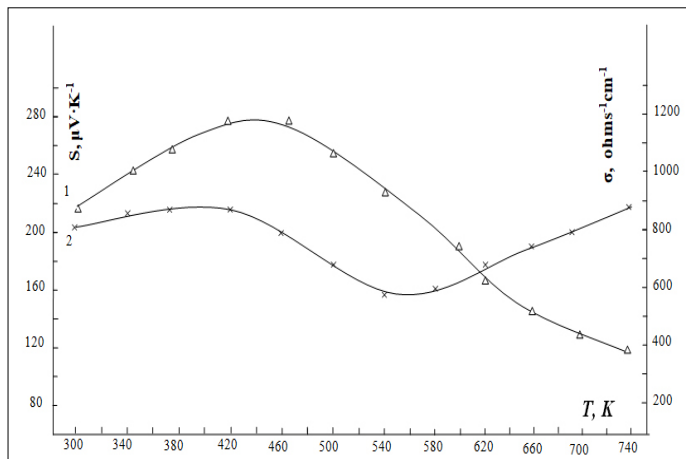


Figure 1. Temperature dependence of the Pb_{0,95}Tb_{0,05}Se alloy for 1 - α - temro-e.d.s. and 2 - σ -electroconductivity

CONCLUSION

Sufficiently high thermoelectric efficiency of the investigated sample $Tb_{0,05}Pb_{0,95}Se$, and preservation of this property in a wide temperature range, allows to consider them as promising thermoelectric materials, and having a very important practical application.

REFERENCES

1. Prokofiev L.V., Rawicz Yu.I., Pshenay-Severin D.A., Konstantinov P.P., Shabaldin A.A. // Semiconductor Physics and Technology. 2010. Vol.44. No. 6. p. 742-748.
2. Aliyev F.F., Hasanov G.A. // Semiconductor Physics and Technology. 2012. Vol. 46. No. 3. p.313-316.
3. Irkhin V.Yu., Irkhin Yu.P.// M. PXД. 2008. p. 476.
4. Alekseeva GT, Vedernikov MB, Gurieva EA, Konstantinov PP, Prokofieva LV Ravich Yu.I.// Semiconductor Physics and Technology. 1998. Vol.32. No. 7. p. 806-810.

bipolar diffusion, in the region of intrinsic conductivity, the electrical conductivity increases (Figure 2, curve 1). From the experience, the thermoelectric efficiency Z is calculated for the temperature interval of the conducted study and based on the obtained values, the temperature dependence of the change is presented in Figure 2, curve 2. It can be seen from the curve that the thermoelectric goodness of the sample $Z > 2 \cdot 10^{-3} T^{-1}$ remains stable in a wide temperature interval 300÷700 K. A monotonic decrease is observed with subsequent temperature increase.

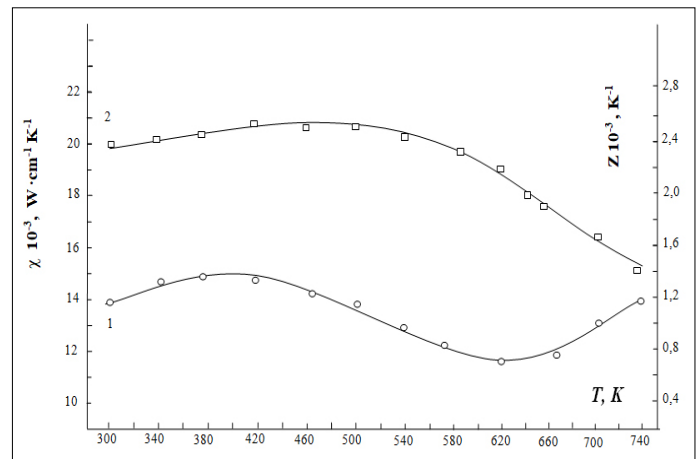


Figure 2. Temperature dependence of Pb_{0,95}Tb_{0,05}Se alloy for c - thermal conductivity coefficient (1) and Z - thermoelectric efficiency (2)

5. O. M. Hasanov, H. A. Adgezalova, J. I. Huseynov Thermal materials based on PbSe-TbSe solid solutions. Applied Physics, Scientific and Technical Journal, 2018, No.2, Moscow.
6. Pavlov L.P. Methods of measurement of parameters of semiconductor materialov. Leningrad, Nauka, 1987, 135 p. [in Russian].
7. Huseynov D.I, Murguzov M. I., Ismailov Sh. S.// Inorganic Materials, 2008, Vol.44, Is. 5, p. 464.
8. Kumar N., Parihar U., Kumar R., Patel K. J., Panchal C. J., Padha N. Effect of Film Thickness on Optical Properties of Tin Selenide Thin Films Prepared by Thermal Evaporation for Photovoltaic Applications // American Journal of Materials Science 2012 - 2(1): 41-45.
9. O.M.Hasanov, H.A.Adgezalova, J.I.Huseynov Prospective thermogenerators based on PbSe-TbSe compounds as sources of alternative energy. ECOLOGICAL, INDUSTRIAL AND ENERGY SECURITY - 2017, Sevastopol, September 11 - 15, 2017.no-technical journal, 2018, No.2, Moscow.