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MAGNETOTHERMOELECTRIC PROPERTIES OF EXTRUDED SAMPLES OF SOLID SOLUTION $Bi_{0.85}Sb_{0.15}$ IRRADIATED WITH GAMMA QUANTA

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Abstract: It has been studied the electrical conductivity (σ), thermal-emf (α), Hall (R_x), and thermal conductivity (χ) coefficients of extruded samples $Bi_{0.85}Sb_{0.15}$ undoped and doped with tellurium, unirradiated and irradiated with gamma quanta at various doses in the temperature range ~77 -300K and magnetic field strength (H) up to ~$74x10^4$ A/m.

It was found that at low doses of irradiation (1 Mrad) in undoped and tellurium-doped samples of the solid solution $Bi_{85}Sb_{15}$ there appear radiation defects, which play the role of donor centers that lead to an increase in the concentration of free electrons n, electrical conductivity σ, thermal conductivity (χ) and a decrease in the coefficient of thermal-emf α. These defects, scattering current carriers, reduce their mobility μ. An increase in the irradiation dose leads to a decrease in the concentration of structural defects arising as a result of plastic deformation of the crystal lattice in individual grains of extruded samples $Bi_{85}Sb_{15}$, an increase in the electron mobility, and an increase in the prevalence of current carrier scattering on lattice vibrations. When irradiated with gamma rays, not only the generation of radiation defects (centers) occurs but also their rearrangement, which leads to a change in electrical and thermal parameters.

Keywords: extrusion, gamma radiation, mobility, texture, defects.

1. Introduction

Single crystals of solid solutions of Bi-Sb systems have high thermo- and magneto-thermoelectric efficiencies, which make them, at present, indispensable materials for creating various electronic converters [1, 2]. The main disadvantage of single crystals of these systems when creating electronic converters on their basis is their low mechanical strength, due to the layered nature of their structure. Samples of solid solutions of Bi-Sb systems, obtained by hot extrusion, have high mechanical strength and are the most effective material for creating various thermo- and magneto-thermoelectric energy converters [3-6].

Various electronic devices, including devices based on solid solutions of Bi-Sb systems, are often used under radiation conditions. Radiation defects, affecting the physical properties of semiconductor materials, significantly change the parameters of devices based on them. Therefore, the study of the influence of radiation defects on the physical properties of crystals of solid solutions of the Bi-Sb system is relevant [7-11].

Plastic deformation, as well as doping of solid solutions with various impurities of the donor and acceptor types, not only leads to the formation of structural imperfections in crystals and hardening of the material but also significantly changes the mobility and concentration of charge carriers [12]. Consequently, at the same time, the thermal-emf, resistivity, and thermal conductivity change. Therefore, when strengthening material to improve its thermoelectric efficiency, it is necessary to take into account the correlation of electrical and mechanical properties and their dependence on the purity of the material and the perfection of crystalline structures.

Extruded samples of the $Bi_{85}Sb_{15}$ solid solution with a grain size of ~630 μm, doped with 0.0005 at.% Te at ~77K, have thermo- and magneto-thermoelectric figures of merit $\sim 6.2 \cdot 10^{-3}K^{-1}$ and $\sim 7.2 \cdot 10^{-3}K^{-1}$, respectively [13].

Therefore, to elucidate the features of the influence of radiation defects on the magneto-thermoelectric properties of solid solutions of the Bi-Sb system, undoped extruded samples $Bi_{0.85}Sb_{0.15}$ and samples doped with 0.0005 at.% tellurium were obtained, their magneto-thermoelectric properties were studied depending on the dose of gamma radiation in temperature range ~77÷300K and the magnetic field strength up to $\sim 74 \times 10^4$ A/m. Non-irradiated samples and the same samples irradiated with 1 Mrad, 10 Mrad, and 50 Mrad doses of gamma quanta were examined.

2. Experimental part

Extruded samples of solid solutions $Bi_{0.85}Sb_{0.15}$ and $Bi_{0.85}Sb_{0.15}$<Te> were obtained in the following technological sequence:

- synthesis of composition from initial components;
- mechanical grinding of the alloy in a porcelain mortar and selection of a fraction with a particle size of ≤ 0.63 mm using a sieve;
- production of briquettes with a diameter of ~30 mm from it by cold pressing at ~300K and at a pressure of ~3.5 T/cm^2 for the next stage;
- extrusion of finely dispersed blanks (briquettes).

The synthesis was carried out by direct co-fusion of the components. The initial substances in a stoichiometric ratio were placed in a quartz ampoule, which had been preliminarily etched in a chromic acid solution and washed with distilled water. Because the thermoelectric properties of low-temperature materials significantly depend on the degree of purity of the components, the initial components of bismuth of “Vi-0000” brand and antimony of “Su-0000” brand were subjected to preliminary purification. Distilled (or doubly sublimated) tellurium T-sCh was used as dopants. Impurities and initial components were weighed with an accuracy of ±0.0001 g. The dopant Te was introduced during synthesis. Samples with a tellurium concentration of 0.0005 at.% were obtained by fusing an appropriate amount of a sample $Bi_{0,85}Sb_{0,15}$ with a concentration of 0.1 at.% Te with a $Bi_{0,85}Sb_{0,15}$sample. The synthesis was carried out in quartz ampoules evacuated to $\sim 10^{-3}$Pa at ~ 673K for 2 hours. During the synthesis, the ampoule with the substance was constantly subjected to swinging. The ampoule with the synthesized substance was abruptly cooled to room temperature by dipping into the water. In the process of extrusion, the technological parameters of extrusion (temperature, extraction speed, etc.) were chosen such that the formation of extruded bars took place under superplasticity conditions without macro- and micro-disturbances. The bending strength of the obtained extruded samples is ~3 times higher than the strength of single-crystal samples of this composition.

Extrusion was carried out on an MS-1000 hydraulic press from a diameter of ~30 mm to a diameter of ~6 mm using special equipment. Technological parameters of extrusion were: $T_{ex.}$=475 ±3K; $R_{ex.}$=480MPa, press movement speed v_{pr}= 0.02 cm/min, extraction ratio -25.

The texture of samples $Bi_{0.85}Sb_{0.15}$<Te> was studied using the XR D8 ADVANCE X-ray facility, Bruker, Germany, by the method described in [14]. X-ray diffraction patterns were recorded at room temperature using a D2 Phaser diffractometer, Brucker. Using the TOPAS-4.2 program, it was shown from the obtained diffraction patterns that the samples are powders of the solid solution $Bi_{0.85}Sb_{0.15}$, which crystallizes in the hexagonal synonym.

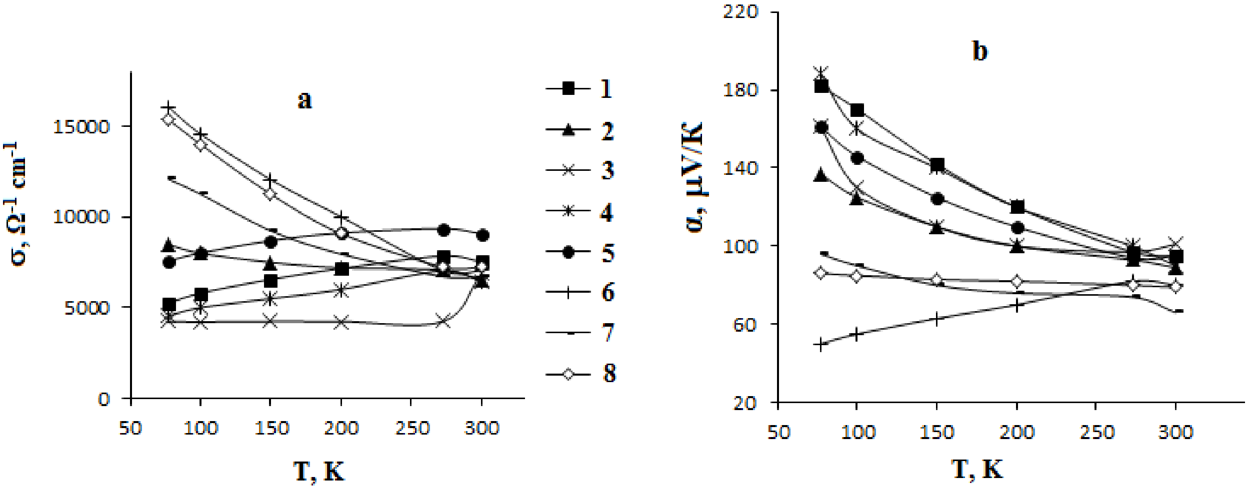
The interplanar distances of bismuth, antimony, and their solid solutions along the main lines are close to each other, so the determination of the phase composition was carried out using bismuth of “Vi-0000” brand.

From the bars obtained on the A207M installation, samples for research were cut out by the method of electric spark cutting in the form of a parallelepiped with dimensions of 3×5×12mm. The damaged layer formed on the sample surface during cutting was removed by electrochemical etching in a $KOH+C_4H_4O_6+H_2O$ solution described in [15]. Samples were annealed in quartz ampoules evacuated to a pressure of ~10^{-3}Pa at a temperature of ~503K for 5 hours.

Electrical and thermal parameters were measured by the method described in [16] parallel and perpendicular to the direction of the extrusion axis. The error in measuring the electrical and thermal parameters was ~3 and 5%, respectively.

3. Results and discussion

The measurement results are presented in Figures 1 and 2 and in the table. In undoped and tellurium-doped extruded samples of $Bi_{0,85}Sb_{0,15}$ solid solutions, with an increase in the dose of gamma irradiation, the concentration of current carriers (n) decreases, and the mobility (μ) increases over the entire temperature range under study, except for the sample irradiated with gamma quanta with a dose of 1 Mrad, where at low doses of irradiation, the concentration of current carriers n in undoped and tellurium-doped samples somewhat increases, while the mobility (μ) decreases. With an increase in the irradiation dose in the samples, n drops significantly, while μ increases. These changes in n and μ correlate well with changes in σ and α (Table).



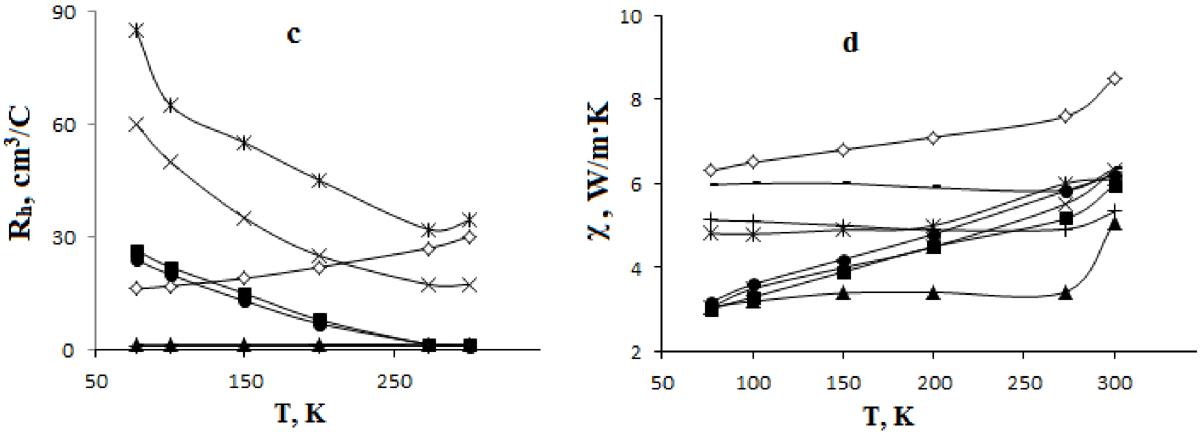


Fig. 1. Temperature dependences of electrical conductivity σ(a), thermal-emf coefficients α (b), Hall (R_x) (c), and thermal conductivity χ *(d) of extruded samples of the* $Bi_{0.85}Sb_{0.15}$ *solid solution doped with tellurium. 1- undoped unirradiated sample; 2-4 - undoped samples irradiated with 1 Mrad, 10 Mrad, and 50 Mrad gamma quanta; 5 - doped with tellurium, non-irradiated; 6-8 - samples doped with tellurium and irradiated with gamma rays of 1 Mrad, 10 Mrad, and 50 Mrad, respectively.*

Table

Electrical parameters of extruded samples of the $Bi_{85}Sb_{15}$ solid solution irradiated with different doses of gamma radiation

Radiation doses	Compositions	at 77 K						at 300 K					
		σ, Ohm^{-1}cm^{-1}	α, μV/K	$R_x\cdot10^{-8}$, cm^3/C	χ, W/cm·K	μ, cm^2/ V·s	n, cm^{-3}	σ, Ohm^{-1}cm^{-1}	α, μV/K	$R_x\cdot10^{-8}$, cm^3/C	χ, W/cm·K	μ, cm^2/ V·s	n, cm^{-3}
0 Mrad	$Bi_{85}Sb_{15}$	5250	-182	-26.5	3.02	139125	$0.24\cdot10^{18}$	7520	-95	-1.43	5.96	10754	$4.4\cdot10^{18}$
	$Bi_{85}Sb_{15}$<Te>	7574	-161	-23.97	3.19	181549	$0.3\cdot10^{18}$	9079	-95	-1.15	6.21	10441	$5.4\cdot10^{18}$
1 Mrad	$Bi_{85}Sb_{15}$	8481	-121	-1.26	3.07	10686	$4.96\cdot10^{18}$	6524	-89	-1.26	5.08	8220	$5\cdot10^{18}$
	$Bi_{85}Sb_{15}$<Te>	15477	-50	-1.08	5.13	16715	$5.79\cdot10^{18}$	7035	-80	-1.08	5.33	7598	$5.8\cdot10^{18}$
10 Mrad	$Bi_{85}Sb_{15}$	4240	-161	-60	3.06	254400	$0.1\cdot10^{18}$	6890	-101	-17.4	6.32	119886	$0.36\cdot10^{18}$
	$Bi_{85}Sb_{15}$<Te>	12084	-56	-11.6	5.97	140174	$0.54\cdot10^{18}$	6713	-66	-21.1	6.36	141644	$0.3\cdot10^{18}$
50 Mrad	$Bi_{85}Sb_{15}$	4552	-188	-85	4.81	386920	$0.07\cdot10^{18}$	6448	-90	-34.3	6.1	221166	$0.18\cdot10^{18}$
	$Bi_{85}Sb_{15}$<Te>	15371	-47	-16.2	6.3	249010	$0.39\cdot10^{18}$	7233	-79	-30.1	8.5	154381	$0.21\cdot10^{18}$

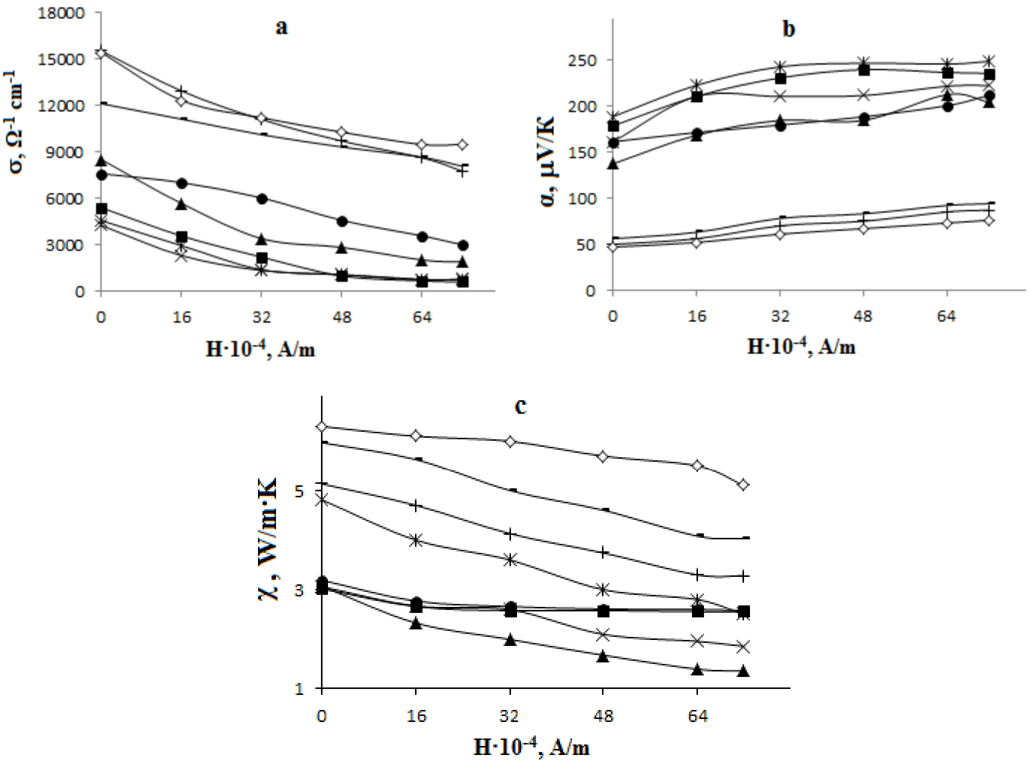


Fig. 2. Dependences of electrical conductivity σ (a), thermal-emf coefficients α (b), and thermal conductivity χ (c) on the magnetic field strength (H) of extruded samples of the $Bi_{0,85}Sb_{0,15}$ solid solution undoped and doped with tellurium at ~77K. The designations are the same as in Fig.1.

The obtained data on R_x show that the low-temperature region of the dependence σ (T) is associated with an increase in the concentration of charge carriers with temperature, but the high-temperature region σ with the temperature dependence of the mobility of charge carriers. From the temperature dependences of σ, α, and R_x, it follows that with an increase in the dose of irradiation of samples, n decreases, and μ increases in the entire temperature range under study, except for the sample irradiated with gamma rays with a dose of 1 Mrad (Figure 1). It can be seen that the nature of the temperature dependences of σ, α, and R_x of non-irradiated pure and doped with 0.0005 at.% Te unmodified samples of the $Bi_{85}Sb_{15}$ solid solution differ from the temperature dependences of irradiated samples with the indicated parameters.

During hot extrusion, the crystallites of a polycrystal gradually change their shape and orientation concerning external deforming forces, as a result of which a predominant crystallographic orientation of grains occurs, i.e. deformation texture. At the same time, as a result of plastic deformation, various defects of the crystal lattice arise in individual grains. These defects are scattering centers for current carriers and reduce their mobility. In this case, these structural defects are predominantly concentrated between the (111) cleavage planes. The degree of texture will depend on the technological parameters of the extrusion process, the grain size, and post-extrusion heat treatment. During heat treatment, the misorientation of grains due to thermal energy can also occur, i.e. change in the degree of the texture of the extruded sample. The concentration of structural defects inside grains also depends on the grain size [5].

With plastic deformation, changes in resistance and thermal-emf are determined by the joint influence of texture and scattering on isotropic disturbances. The change in the Hall coefficient is mainly determined by the changes in the preferential orientation of polycrystals that occur during plastic deformation [17], which occur at the initial stage of deformation. These factors should significantly change the thermoelectric properties of solid solutions of the Bi-Sb systems.

In non-irradiated samples $Bi_{0.85}Sb_{0.15}$, doping with tellurium, creating donor centers does not change the course of σ (T), however, it significantly increases σ relative to σ of a pure sample in the range of ~77-300K. In these samples, R_x monotonically decreases with increasing temperature. In samples, $Bi_{0.85}Sb_{0.15}$ doped with tellurium and irradiated with different doses of gamma rays at low temperatures, σ greatly increases and, at the same time, the nature of the temperature dependence changes. For all samples doped with tellurium and irradiated with gamma quanta, the temperature dependences typical for the region of impurity conduction are also typical. Such a dependence σ (T) can be associated with the temperature dependence of mobility (μ) and the concentration of charge carriers (n).

For non-irradiated samples $Bi_{85}Sb_{15}$<Te>, it can be seen from the dependences $R_x(T)$ that a strong change in Rx and, consequently, in the concentration of charge carriers falls in the temperature range below 270K. As the temperature rises, the change in $R_x(T)$ slows down much. For samples $Bi_{85}Sb_{15}$<Te> irradiated with gamma rays of 10 and 50 Mrad, R_x decreases monotonically with temperature, and a strong change in $R_x(T)$ is observed for heavily irradiated samples. For samples doped with tellurium and irradiated with gamma rays of 1 Mrad, which have the highest concentration of charge carriers among the samples under study, R_x is almost independent of temperature.

The Hall mobility μ of charge carriers, calculated from the ratio $\mu=R_x\sigma$, for all samples decreases with increasing temperature. Doping with tellurium and irradiation with gamma quanta lead to a decrease in mobility relative to the undoped unirradiated sample. With an increase in the radiation dose, the degree of n also changes depending on $\mu \sim T^{-n}$.

In samples undoped and doped with tellurium, not irradiated by gamma quanta, the absolute value of the thermoelectric coefficient α decreases with increasing temperature. Irradiation leads to a decrease in the absolute value of α in the range of 77-300K. In this case, the course of the temperature dependence changes in the irradiated samples. This behavior of α correlates well with the temperature dependence of the electrical conductivity.

For samples $Bi_{85}Sb_{15}$ doped with tellurium and irradiated with gamma rays, the course of the temperature dependence α acquires the form characteristic of the impurity conduction region.

In pure samples, the influence of gamma radiation on α, with a significant change in σ, shows that during irradiation, μ of charge carriers mainly changes, due to a decrease in the concentration of scattering centers for electrons. When samples are irradiated with gamma quanta, structural defects are “healed”, which leads to an increase in μ of current carriers. In samples $Bi_{85}Sb_{15}$ doped with tellurium atoms, the significant effect of gamma radiation on α and σ in the samples shows that radiation defects, which play the role of donor centers, increase the concentration of charge carriers.

Thermal conductivity for all samples increases with temperature. Irradiation does not affect the course of the temperature dependence of χ, however, it increases the thermal conductivity (except for the sample irradiated at 1 Mrad) over the entire temperature range of the study, relative to the thermal conductivity of the non-irradiated sample. Doping with tellurium in samples of the $Bi_{85}Sb_{15}$ solid solution leads to an increase in the total thermal conductivity and the Hall mobility at ~77K.

At ~77K, the thermal energy in the $Bi_{0.85}Sb_{0.15}$ solid solution is mainly transferred by lattice vibrations and conduction electrons [18]. Based on this, according to the expressions $\chi_r=\chi-\chi_e$ (1) and $\chi_e=L\sigma T$ (2), the electronic (χ_e) and lattice (χ_r) components of thermal conductivity are calculated, respectively. Here χ is the total measured thermal conductivity, σ is the electrical conductivity at a given temperature T, $L= A(k/e)^2$ is the Lorentz number, k is the Boltzmann constant, e is the electron charge. The value of A was estimated from the dependence of A on the thermal-emf coefficient [19].

The calculated electronic component of thermal conductivity χ_e at ~77K for samples unirradiated and irradiated with γ-quanta (1Mrad, 10 Mrad, 50 Mrad) are 0.72; 1.2; 0.59; 0.6 for undoped samples and 1.0; 2.1; 1.7; 2.1 W/m·K for tellurium-doped samples, respectively. In this case, the lattice component χ_r for the above samples, calculated by the formula (1) is: 2.3; 1.87; 2.47 and 4.21 for undoped samples and 2.19; 3.03; 4.27: 4.2 W/m·K for tellurium-doped samples, respectively. It can be seen that at ~77K, in the studied samples heat is transferred mainly for samples irradiated with gamma rays (1; 10 and 50 Mrad, respectively) by lattice vibration. In irradiated samples, with an increase in the dose of γ-irradiation, the values of the lattice part of the thermal conductivity χ_r increase. This means that at low temperatures, with an increase in the irradiation dose, the increase in the total thermal conductivity χ in the samples is due to the increase in χ_r.

Thus, the temperature dependences of the electrical parameters of pure and tellurium-doped extruded samples of the $Bi_{85}Sb_{15}$ solid solution irradiated with different doses of gamma rays are explained based on the temperature dependences of μ and n of charge carriers.

The introduction of radiation defects (RD) into the crystal lattice of a semiconductor leads to a change in its electrical and thermal parameters.

Irradiation is rather a “reverse” (opposite) process of doping a semiconductor material with impurities. By introducing a chemical impurity into a semiconductor, we thereby deviate the chemical potential of the semiconductor to a position specified by the doping level relative to some of its characteristic position FS for a given material. In this case, the limiting level of equilibrium doping is always reached - the limiting position of the Fermi level in the case of doping the semiconductor with donor (acceptor) impurities, respectively. The limitation on the level of semiconductor doping with chemical impurities is associated with various processes of self-compensation of the material, the more effective result of irradiation of the doped material is the "return" of the Fermi level from the position specified by the doping level to the position F_{lim} [20–22].

An irradiated semiconductor is a highly compensated material. This is what makes it possible to consider the radiation modification of the properties of a semiconductor as a process “reverse” to doping with chemical impurities, as a result of which the initial electrical activity of the material decreases and the degree of its compensation increases.

The effect of irradiation on the electrical and thermal properties of extruded samples of the $Bi_{85}Sb_{15}$<Te> solid solution shows that a heavily irradiated semiconductor is always a material with a low concentration of free charge carriers, a high concentration of charge bound to defects, and a degree of compensation of radiation donors and acceptors close to unity.

Under irradiation, a process of lowering the initial electrical activity of the material occurs in the sample, as a result of which the Fermi level is shifted from its initial position and is fixed near a certain level position characteristic of a given semiconductor. The electronic parameters of the irradiated material depend on the features of the band spectrum of the semiconductor in the energy range near its minimum band gap, i.e. are determined by the position of the Fermi level relative to the nearest extrema of the conduction band or valence band.

Irradiation leads to a decrease in the concentration of structural defects arising as a result of plastic deformation of the crystal lattice in individual grains of extruded $Bi_{85}Sb_{15}$ samples, an increase in the electron mobility, and an increase in the prevalence of current carrier scattering on lattice vibrations. These assumptions are also confirmed in the dependence of σ and α on the magnetic field strength.

The transverse magnetoresistance in weak fields is proportional to the square of the magnetic induction B and the square of the mobility of charge carriers μ [23].

$$\Delta\rho/\rho_0 = A\,\mu^2 B^2 \qquad (1)$$

where coefficient A depends on the mechanism of current carrier scattering. The experimental results on the dependence of $\Delta\rho/\rho_0$ on B^2 are in good agreement with the value of A (A=1.18) for electron scattering in $Bi_{85}Sb_{15}$ samples. This is also evidenced by the regularities in the dependence of the Hall coefficient on the magnetic field strength in the studied $Bi_{85}Sb_{15}$ samples. Similar dependencies are also obtained at high (up to ~300 K) temperatures. However, due to a decrease in the mobility of current carriers with increasing temperature, these dependencies are somewhat weakened.

The values of χ are in good agreement with the above considerations obtained from measurements in a magnetic field.

The radiation-stimulated increase in charge mobility (due to the introduction of acceptor-type point defects and local mechanical stresses, which are certainly higher), is probably associated with the specifics of the interaction of radiation centers and with defects resulting from plastic deformation of the crystal lattice in individual grains

The results of the obtained data indicate that, under irradiation with gamma rays, not only the generation of radiation defects (centers) occurs, but also their rearrangement. Restructuring significantly depends on the initial level of modification of the ingot, from which the corresponding samples for research were made.

4. Conclusion

From the obtained experimental data, it is assumed that at low doses of irradiation (1 Mrad), in undoped and tellurium-doped samples of the $Bi_{85}Sb_{15}$solid solution, radiation defects appear, playing the role of donor centers, which lead to an increase in the concentration of free electrons n and electrical conductivity σ, and a decrease in the thermo-emf coefficient α. These defects, scattering current carriers, reduce their mobility μ. An increase in the irradiation dose leads to a decrease in the concentration of structural defects arising as a result of plastic deformation of the crystal lattice in individual grains in extruded $Bi_{85}Sb_{15}$ samples, an increase in the electron mobility, and an increase in the prevalence of current carrier scattering on lattice vibrations. When irradiated with gamma rays, not only the generation of radiation defects (centers) occurs but also their rearrangement, which leads to a change in electrical and thermal parameters.

These assumptions are also confirmed in the dependences of σ, α, and χ on the magnetic field strength.

References

1. V.S. Zemskov, A.D. Belaya, S.A. Roslov, et al., Thermoelectric properties of solid solutions Bi-Sb // Izv. Academy of Sciences of the USSR. Metalli. 1978. No. 1.pp.73-76.
2. L.A. Belozerova, Research of Bi-Sb alloys for thermoelectric cooling devices // Kholodilnaya tekhnika i tekhnologiya. Kyiv: Tekhnika. 1976. Ed. 23. pp. 52-54.

3. M.P. Banaga, O.B. Sokolov, T.E. Benderskaya, L.D. Dudkin, A.B. Ivanova, I.I. Fridman, Features of the structure and thermoelectric properties of extruded samples of $Bi_{0.88}Sb_{0.12}$ // Izv. Academy of Sciences of the USSR. Inorg. materials. 1986. V.22. No. 4. pp. 619-622.
4. M.M. Tagiyev, Z.F. Agayev, D.Sh. Abdinov, Thermoelectric properties of extruded samples $Bi_{85}Sb_{15}$// Inorg. materials. 1994. V.30. No. 3. pp. 375-378.
5. M.M. Tagiyev, Influence of grain sizes and lead impurities on the thermoelectric properties of extruded samples of the $Bi_{0.85}Sb_{0.15}$ solid solution, Inorg. materials. 2021. V.57. No. 2. pp. 119-124.
6. M.M. Tagiyev, S.Z. Jafarova, A.M. Ahmadova, G.D. Abdinova // Russian Journal of Physics. 2019. V.62 No. 3 pp.510-516.
7. I.A. Abdullaeva, G.D. Abdinova, M.M. Tagiyev, and B.Sh. Barkhalov, Effect of Gamma Irradiation on the Electrical Properties of Extruded Bi85Sb15⟨Te⟩ Samples // Inorganic Materials, 2021, Vol. 57, No. 9, pp. 887–892.
8. M. Paulescu, D. Vizman, M. Lascu, R. Negrila, M. Stef. Experimental study of proton irradiation effect on silicon solar cells // Physics Conference TIM 15-16. At: Timisoara, Romania. 2017.V.1796 (1). doi: 10.1063/1.4972388
9. S. Park, J.C. Bourgoin, H. Sim, C. Baur, V. Khorenko, O. Cavani , J. Bouerois, S. Picard, B. Boizot. Space degradation of 3J solar cells: I—Proton irradiation/Progr. Photovot. Res. Appl., 2018.V.26. №10. P.778-788. https://doi.org/10.1002/pip.3016
10. I.A. Abdullayeva, G.D. Abdinova, M.M, Tagiyev, O.A. Samedov, Effect of γ-radiation on magnetothermoelectric properties of the extruded samples of $Bi_{85}Sb_{15}$ <Te> solid solution// International Journal of Modern Physics B, Vol. 35, No. 07, 2150099 (9 pages) (2021) https://doi.org/10.1142/S0217979221500995
11. O.A. Oraby, M.F. El-Kordy, H.T. El-Madany, F.H. Fahmy. UASat Solar Array Design and Performance Characteristics // Int. J. Sci., Engin. Technol. Res. (IJSETR) 2014. V.3. №2. P.167-172.
12. N.A. Sideronko, Z. M. Dashevsky, Effective Bi–Sb Crystals for Thermoelectric Cooling at Temperatures of T ≲ 180K // Russian Journal PTS (Physics and technology of semiconductors) Semiconductors. 2019. V.53. №5. pp.686-690. doi:10.1134/S1063782619050245
13. M.M. Tagiyev, G.D. Abdinova, B Sh, Barkhalov Russian Journal of Physics Russian Physics Journal, volume 64, pp. 1592–1598 (2022).
   Extruded Material Based on $Bi_{0.85}Sb_{0.15}$ for Thermoelectric Converters
14. D.M. Hayker, L.S. Zevin, X-ray diffractometry, M.: Fizmatgiz. 1963. P. 380.
15. T.D. Aliyeva, D.Sh. Abdinov, E.Yu. Salayev, Influence of surface treatment of thermoelectric materials on the properties of thermoelements made from solid solutions of Bi_2Te_3-Bi_2Se_3 and Bi_2Te_3-Sb_2Te_3 systems, Izv. AN. USSR. Inorgan. materials. 1981. T17. No. 10. pp. 1773-1776.
16. A.S. Okhotin, A.S. Pushkarsky, R.P. Borovikova, V.A. Smirnov, Methods for measuring the characteristics of thermoelectric materials and converters, M.: Nauka, 1974. p.168.
17. A.N. Dubrovina, L.A. Leonteva, G.A. Drozdova et al. Influence of the second phase on deformations and recrystallization of alloys based on Bi_2Te_3 // Inorganic materials. 1981. Vol. 17. No. 4, pp. 613-617
18. M.M. Tagiyev Z.F. Agayev, D.Sh. Abdinov, Thermal conductivity of $Bi_{0,85}Sb_{0,15}$ doped with tellurium, Inorg. materials. 1994. V.30. No. 6. pp. 776-778.
19. V.S. Oscotsky, I.A. Smirnov, Defects in crystals and thermal conductivity. L.: Nauka. 1972. p. 160
20. A. K. Pikayev, Dosimetry in Radiation Chemistry, M.: Nauka. (1975) 232.

21. V.N. Brudny, Radiation defects in II-IV-V2 semiconductors (review), Izv. Vuzov. Fizika. 1986. No. 8. pp. 84 – 97.
22. Paulescu M., Vizman D., Lascu M., Negrila R., Stef M. Experimental study of proton irradiation effect on silicon solar cells / Physics Conference TIM 15-16. At: Timisoara, Romania. 2017.V.1796 (1). doi: 10.1063/1.4972388
23. A.F. Ioffe, Semiconductor thermoelements, M.-L.: Nauka, 1960, p. 186.

МАГНИТОТЕРМОЭЛЕКТРИЧЕСКИЕ СВОЙСТВА ЭКСТРУДИРОВАННЫХ ОБРАЗЦОВ ТВЕРДОГО РАСТВОРА $Bi_{0,85}Sb_{0,15}$, ОБЛУЧЕННЫХ ГАММА-КВАНТАМИ

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Резюме: Исследованы электропроводность (σ), коэффициенты термо-эдс (α), Холла (R_x) и теплопроводности (χ) экструдированных образцов $Bi_{0,85}Sb_{0,15}$ нелегированных и легированных теллуром, не облученных и облученных гамма-квантами при различных дозах в температурном интервале ~77-300K и напряженности магнитного поля (H) до ~$74x10^4$ A /м.

Выяснено, что при малых дозах облучения (1 Мрад) в нелегированных и в легированных теллуром образцах твердого раствора $Bi_{85}Sb_{15}$ возникают радиационные дефекты, играющие роль донорных центров, которые приводят к росту концентрацию свободных электронов n, электропроводности σ, теплопроводности(χ) и уменьшению коэффициента термо-эдс α. Эти дефекты, рассеивая носители тока, уменьшают их подвижность μ. Рост дозы облучения приводит к уменьшению концентрации структурных дефектов, возникающих в результате пластической деформации кристаллической решетки в отдельно взятых зернах экструдированных образцов $Bi_{85}Sb_{15}$, увеличению подвижности электронов и усилению превалирования рассеяния носителей тока на колебаниях решетки. При облучении гамма- квантами происходит не только генерация радиационных дефектов (центров), а также их перестройка, которая приводит к изменению электрических и тепловых параметров.

Ключевые слова: экструзия, гамма-радиация, подвижность, текстура, дефекты.

QAMMA KVANTI İLƏ ŞÜALANAN $Bi_{0,85}Sb_{0,15}$ BƏRK MƏHLUNUN EKSTRUZİYA EDİLMİŞ NÜMUNƏLƏRİNİN MAQNİTOTERMOELEKTRİK XÜSUSİYYƏTLƏRİ

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Xülasə: Aşqarlanmamış və tellurla aşqarlanmış, şüalanmamış və qamma-kvanta ilə müxtəlif dozalarda şüalanmış ekstruziya edilmiş $Bi_{0,85}Sb_{0,15}$ nümunələrinin elektrik keçiriciliyi (σ), termo-emf (α), Hall (R_x) və istilik keçiricilik (χ) əmsalları ~77-300K temperatur diapazonunda və ~$74x10^4$ A/m-ə qədər maqnit sahəsində (H) araşdırılmışdır.

Müəyyən edilmişdir ki, $Bi_{85}Sb_{15}$ bərk məhlulunun aşqarlanmamış və tellur ilə aşqarlanmış nümunələrində şüalanmanın aşağı dozalarında (1 Mrad) donor mərkəzləri rolunu oynayan radiasiya qüsurları yaranır ki, bu da sərbəst elektronların n konsentrasiyasının, elektrik keçiriciliyinin σ, istilik keçiriciliyinin (χ) artmasına və termo-emf α əmsalının azalmasına səbəb olur. Bu qüsurlar, cərəyan daşıyıcılarını səpərək, onların hərəkətliliyini μ azaldır. Şüalanma dozasının artması ekstruziya edilmiş $Bi_{85}Sb_{15}$ nümunələrinin ayrı-ayrı dənələrində kristal qəfəsin plastik deformasiyası nəticəsində yaranan struktur qüsurlarının konsentrasiyasının azalmasına, elektronların hərəkətliliyinin artmasına və qəfəs vibrasiyaları üzərində cərəyan daşıyıcısının səpilməsinin güclənməsinə səbəb olur. Qamma şüaları ilə şüalandıqda təkcə radiasiya qüsurlarının (mərkəzlərinin) yaranması deyil, həm də onların yenidən təşkili baş verir ki, bu da elektrik və istilik parametrlərinin dəyişməsinə səbəb olur.

Açar sözlər: ekstruziya, qamma şüalanma, hərəkətlilik, tekstura, qüsurlar.