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ABSTRACT

of the dissertation for the degree of Doctor of Science

**PHYSICO-CHEMICAL BASES OF ACQUISITION
TECHNOLOGY OF NEW MATERIALS AND STRUCTURES
BASED ON INDIUM TELLURIDES, ELECTRONIC AND
THERMAL PHENOMENA IN THEM**

Speciality: 2220.01 – Semiconductor physics

Field of science: Physics

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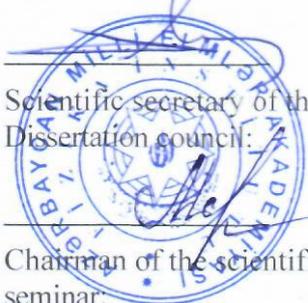
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GENERAL DESCRIPTION OF WORK

Relevance of the research topic: Much attention is paid to the study of the properties of semiconductor compounds with complex composition and solid solution crystals and their acquisition in modern electronic techniques, especially in the field of materials science. Such materials are used effectively in optoelectronic devices, thermo- and photoelectric power circuits, magnetic and electronic memory elements, tenzo- and thermometric devices, nanoelectronics and other new techniques. In order to create stable and repetitive efficient solid-state structures, their material acquisition technologies must be well developed, and different types of energy converters with parameters controlled by these materials, as well as electronic means of information creation, must be simplified and economically feasible. Although the The solution of these problems can be solved qualitatively in semiconductor materials such as silicon, germanium, gallium arsenic, complex compound combination and crystals of solid solution rarely find reliable application areas. For this reason, intensive research is currently being carried out in many developed countries of the world, including our country, to obtain technology of complex compound electronic equipment materials and to expand their application areas.

As an example of such promising semiconductor materials, we can point to $A^{III} B^{VI} (A_2^{III} B_3^{VI})$ compounds and crystals of solid solutions obtained on their basis. The interest in semiconductors in this class is high because of the electronic configuration of the elements included in the composition, the nature and type of chemical contact, adjustable amount of defects caused by halogen, and many other physico-chemical and technological aspects, such as these, make it possible to determine in advance their reliable acquisition, the reliability of their operation in devices. The common features of $A^{III} B^{VI} (A_2^{III} B_3^{VI})$ types of compounds are that they interact with other semiconductor compounds in simple composition way by forming single-phases, their specific electrical resistance is relatively high, their charge carriers have low mobility and overall thermal conductivity, they have high thermo-e.m.f coefficient, they retain

their semiconductor properties even when melted and they are sensitive to optical radiation, etc. they concentrate on such important scientific-practical aspects.

Among these types of compounds, indium telluride is especially noticeable. Although the acquisition and study of indium telluride was initiated at the beginning of the last century, there is still intensive research in this area. Thus, there is an urgent need to clarify the existence of phase transitions in these compounds and the issue of their disputable numbers. Also, an interesting feature of the aforementioned compounds is that most elementary chemical elements present themselves as inactive additives in them. For this reason, it is more advisable to influence both InTe and In₂Te₃ with complex combinations. Application areas of indium tellurides can be expanded by applying compounds with powerful thermoelectric, magnetic, photoelectric and other properties.

Indium monotelluride differs from indium sulfide and seleniide, which is structural analogues, and are of TIS nature. Thus, the indium atoms in InTe have different coordination and this factor has a powerful effect on the physical properties of the compound, and especially on its magnetic properties, which cause it to be diamagnetic.

Specific features are also characteristic of In₂Te₃ compound. The combination of In₂Te₃ has so many interesting properties that, one issue of the well-known journal " Physics of the Solid State" (№11), which is published in Russia and currently having an impact factor, is dedicated to the results obtained from the study of its properties. Uncertainty of the number of modification transitions, in the cubic crystal structure, the cage constant is three times larger than that of conventional cubic structures, and finally, and finally the indium atoms settle in only two-thirds of the cation hemisphere, meaning that 1/3 of the crystalline cage consists of gaps (defects) for the composite elements, which makes this compound scientifically interesting. Studies show that the high-resistance semiconductor In₂Te₃ can be converted into an efficient thermoelectric material as well as vacuum type defects can be controlled successfully by the effect of substance additives with high thermoelectric properties.

Taking into account the above factors, it can be concluded that acquisition of new compound semiconductor materials which are of great scientific and practical importance, clarifying the nature of physical and chemical interactions between indium telluride and binary, triple and even quaternary compounds, the study of their thermal, physical, electronic, thermo- magnetic and other properties, and the determination of charge and heat transfer mechanisms is an urgent issue of modern electronic equipment. It would be useful to create new solid-state structures based on the InTe and In₂Te₃ compounds, especially active elements for alternative energy converters. The present dissertation is devoted to the solution of these problems.

Object and subject of research:

The object of the study is multicomponent solid-solution compounds and structures with the presence of indium tellurides. The subject of the research is the study of the physical-chemical, electronic-thermal, photoelectric and voltampere properties of these semiconductors.

Research aims and objectives:

The purpose of the research is to clarify the nature of the interaction between indium tellurides and multicomponent semiconductors, to determine the mechanisms of the effect of temperature, composition, light flux, electric and magnetic fields on the electronic-thermal properties of the discovered solid solution and new compounds, and to determine the use of the obtained materials and structures in certain fields of application. .

In order to achieve the goal, the following tasks were set and solved in front of the dissertation work:

1. between binary, ternary and quaternary semiconductor compounds containing 3d-, s- and p- elements and indium tellurides [InTe-(Cr₂Te₃, CoTe₂, TlGaTe₂, TlInSe₂, TlBiTe₂, CuGaTe₂, Bi_{1,3}Sb_{0,7}Te₃, CuCr₂Te₄, Cu₂ZnSnS₄)] vø [In₂Te₃-(MnTe₂, Ni₃Te₄, CuInSe₂, CuGaSe₂, Cd_{0,9}Zn_{0,1}Te, CuCr₂S₄, Cu₂Ga₄Te₇, Cu₂In₄Te₇, CuZn₂InTe₄), (CuTe-Cr₂Te₃) clarifying of the nature of phase equilibrium;

2. investigation of physico-chemical, thermal-physical, photoelectric, VAX and crystallophysical properties of detected phases;

3. researching the dependence of the kinetic coefficients of homogeneous phases on the composition, temperature, and the effect of the light flood; 4. development of the

4. technology of creating electronic signal amplifiers, information transmitters, electronic switches and active elements of alternative energy sources from the studied materials.

Research methods:

The research methods include the production of alloys by vibrating direct synthesis technology and their high-precision differential-thermal analysis devices (HTP-73 and TERMOSKAN-5 pyrometers), X-ray analysis (DRON-3, DUNKER-2D and D2 PHASER devices), microstructure analysis and microhardness determination (МИМ-7, PMT-3, ViewMet microscopes, MicroMet-5101 microhardness tester) methods, as well as measurement of thermoelectric, galvano- and thermomagnetic properties by the compensation method, thermal conductivity by the stationary method in a wide temperature range, photoelectric properties spectral, voltamperes and voltfarads includes the study of its characteristics. The "hot wall" version of the thermal vaporization unit and magnetron sputtering technologies were used to obtain thin layers and solid structures. Confirmation of the existence of the new compounds discovered was proved by computer modeling.

The main provisions for the defended:

1. The nature of the phase equilibrium in the investigated semiconductor systems, the nature of changes of the phase transitions occurring in indium tellurides depending on the composition and temperature, and the determination of the degree of stability (stability) of the formed phases based on the calculation of thermodynamic functions. The consequences of the state of chemical bonding in the detected solutions.

2. Determination of optimal compositions and crystallization regimes of effective semiconductor materials for electronic engineering using the characteristics of phase equilibrium processes

found in the studied systems. Features of regularities of physico-chemical processes occurring by changing the amount and type of 3d-elements in the composition of alloys.

3. Anomalies and regularities observed in the composition and temperature dependence of the properties of homogeneous alloys. In them, the complexity of charge carrier scattering mechanisms and the causes of additional thermal resistance and the diversity of the nature of electron-heat transport.

4. The energy diagram and energetic parameters of the heterojunction created with indium monotelluride, the effect of the manufacturing technology conditions of the constructed solid-state thermoelectric and solar elements, a thin-film thermoresistor and a signal amplifier with a Peltier element, p-n junction and electronic keys on the main application characteristics and operating parameters.

Scientific novelty of the study:

1. State diagrams of multi-component semiconductor systems with the presence of InTe and In₂Te₃ compounds were constructed, and the nature of phase equilibrium in them was clarified. New compounds with complex composition (CuIn₃Te₅, InCr₂Te₄, TlInGaTe₂, CuCr₂Te₄) were obtained in these systems and their physicochemical and electrophysical properties were studied.

2. In order to clarify the existence of CuCr₂Te₄ compound, which is the primary component, and the nature of its formation, in addition, the interaction between CuTe and Cr₂Te₃ compounds was studied, and the phase diagram of the CuTe-Cr₂Te₃ system was constructed for the first time.

3. [In₂Te₃-(MnTe₂, Ni₃Te₄, Cd_{0,9}Zn_{0,1}Te, CuZn₂InTe₄)], [InTe-Cr₂Te₃, TlGaTe₂, TlBiTe₂, CuZnSnS₄], (Cu₂Ga₄Te₇)_{1-x}(In₂Te₃)_x temperature dependences of electrophysical, galvano- and thermomagnetic and other properties of solid solution and new compounds (CuIn₃Te₅, InCr₂Te₄, TlInGaTe₂, CuCr₂Te₄) were studied, the mechanism of electron-phonon scattering in these substances was determined.

4. The CuGa₂InTe₅ thermoelectric parameters of the specified (Cr₂Te₃)_{1-x}(In₂Te₃)_x, (CuCr₂Te₄)_{0,99}(InTe)_{0,01} solid solutions and

compounds were calculated, and $\text{Cu}_2\text{ZnSnS}_4$, $(\text{Cr}_2\text{Te}_3)_{1-x}(\text{In}_2\text{Te}_3)_x$, $(\text{CuCr}_2\text{Te}_4)_{0,99}(\text{InTe})_{0,01}$ was selected and recommended for use in thermoelectric energy converters.

5. The degree of application of solid solution $(\text{CuInSe}_2)_{1-x}(\text{In}_2\text{Te}_3)_x$ electrical, photoelectric, voltampere and other properties of its components in the preparation of solar cells and creation of promising solid-state structures.

6. Based on the results of the investigated complex properties and efficient compositions, the constructions of thermoelectric and solar elements were worked out, thin-film heterojunctions and converting keys were prepared and their application parameters were determined.

7. An electronic circuit was created for measuring weak signals using the received material and solid $n\text{-(Bi}_{1,3}\text{Sb}_{0,7}\text{Te}_3)_{1-x}(\text{InTe})_x$, $p\text{-(CuCr}_2\text{Te}_4)_{0,99}(\text{InTe})_{0,01}$ structures, its application parameters were calculated.

Theoretical and practical significance of the research:

1. In the state diagrams [$\text{InTe-(Cr}_2\text{Te}_3, \text{CoTe}_2, \text{TlGaTe}_2, \text{TlInSe}_2, \text{TlBiTe}_2, \text{CuGaTe}_2, \text{Bi}_{1,3}\text{Sb}_{0,7}\text{Te}_3, \text{CuCr}_2\text{Te}_4, \text{Cu}_2\text{ZnSnS}_4)$] $v\varnothing$ [$\text{In}_2\text{Te}_3\text{-(MnTe}_2, \text{Ni}_3\text{Te}_4, \text{CuInSe}_2, \text{CuGaSe}_2, \text{Cd}_{0,9}\text{Zn}_{0,1}\text{Te}, \text{CuCr}_2\text{S}_4, \text{Cu}_2\text{Ga}_4\text{Te}_7, \text{Cu}_2\text{In}_4\text{Te}_7, \text{CuZn}_2\text{InTe}_4)$], ($\text{CuTe-Cr}_2\text{Te}_3$) sufficient scientific bases and technological information have been collected.

The theoretical thermodynamic functions of the complex composition $(\text{CuCr}_2\text{S}_4)_{1-x}(\text{In}_2\text{Te}_3)_x$, InCr_2Te_4 , TlInGaTe_2 crystals were calculated, and the existence of the InCr_2Te_4 compound was confirmed by computer prediction.

When purchasing new materials and structures for electronic equipment based on solid solutions and compounds, precise technological modes can be selected from these diagrams.

2. Solid-state structures for thermoelectric, photoelectric, measuring equipment and solar energy converters, thermoresistor, Peltier effect amplifier and thin-film electronic key structures have been created from the studied semiconductor materials, which can be widely used in the production of electronic equipment devices.

3. Masters, young scientists of the republic, technologists, graduate students, etc. can effectively use state diagrams, thermodynamic calculations and the results obtained from the study of physical parameters.

4. Since the new results are considered effective survey information for electronic materials science, they have been included in the database and survey books related to the relevant fields of technology and can be done in the future.

Research approval and application:

The scientific results obtained in the dissertation were reported and discussed at the following international, republican and intra-university conferences: 1) Proceedings of the 7th International Scientific and Technical Conference "Actual Problems of Solid State Electronics and ME" Divnomorskoe, Russia, September 17-22, 2000, Taganrog, Russia, 2) 47th Scientific and Technical Conference of AzTU faculty, 2000 AzTU, Baku, Azerbaijan; 3) Prof. A.A. Republican conference dedicated to the 70th anniversary of Abdullayev, 2001 AzTU Baku, Azerbaijan, 4) "Physico-chemical analysis and inorganic materials science". 7th Scientific and Technical Republican Conference 2001, BSU, Baku, Azerbaijan; 5) "H. Aliyev and scientific and technical progress in Azerbaijan", May 7-8, 2003 AzTU, Baku, Azerbaijan; 6) "Physics-2005" international conference, June 7-9, 2005, BSU, Baku, Azerbaijan; 7) XIX National Chemistry Congress, September 30-October 4, 2005, Ege Üniversitesi, Izmir, Turkey, 8) 53rd Scientific and Technical Conference of AzTU faculty and graduate students 2006, AzTU, Baku, Azerbaijan; 9) 20, 21, 24, 25, 26, 27, 28, 29, 31 conferences of the National Chemistry Congress in Turkey (29 Haziran-3 Temmuz 2006 Kayseri; 23-24 August 2007 Malatya; 29 Haziran-2 Temmuz 2010 Zonguldag; 27 Haziran-2 Temmuz 2011 Erzurum; 1-6 October 2012, Mugla, 23-28 August 2015, Çanakkale; 15-21 August 2016, Mersin; 10-14 September 2017, Ankara; 10-14 September 2019, Istanbul); 10) Republican scientific-practical conference "Innovation Technologies in Education" dedicated to the 60th anniversary of AzTU 2010 Baku, Azerbaijan; 11) IV Republican conference on modern problems of physics, December 24-25, 2010, Baku,

Azerbaijan; 12) "Problems of metallurgy and materials science" international conference dedicated to the 90th anniversary of H. Aliyev, April 29-30, 2013, AzTU, Baku, Azerbaijan; 13) 9th International Conference on Technical and Physical Problems of Electrical Engineering, September 9-11, 2013, Istanbul, Turkey;), Baku, Azerbaijan; 15) 11th international congress "Cardiostim", February 27-March 1, 2014, St. Petersburg, Russia; 15) 31st International Physical Congress, July 21-24, 2014, Bodrum, Turkey; 16) 11th International Conference on Technical and Physical Problems of Electrical Engineering, September 10-12, 2015, Bucharest, Romania; 17) 9th International Physics Conference of the Balkan Physics Union, August 24-25, 2015, Istanbul, Turkey; 18) 32th International Physical Congress, 2015, Bodrum, Turkey; 19) Prof. 5th international scientific-practical conference "Modern problems of the physics of metals" dedicated to the 80th anniversary of Tahir Panahov, June 10-11, 2016, Baku, Azerbaijan; 20) 33rd International Physical Congress, Turkey, Bodrum, 2017; 21) XIII Russian Conference on Physics of Semiconductors, Russia, October 2-6, 2017, Yekaterinburg, Russia; 22) "Heydar Aliyev and the Azerbaijani Army" scientific-practical conference, Ministry of Defense of the Republic of Azerbaijan, Baku, 2018; 23) 7th Rostocker International conference "Thermophysical properties for technical thermodynamics", July 27-26, 2018, Rostock, Germany; 24) 35th International Physical Congress, 04-08 September 2019 Bodrum, Turkey; 25) 31st National Chemistry Conference, Yıldız Technical University, September 10-13, Istanbul, Turkey 26) 10th Rostocker International conference: "Technical Thermodynamics: Thermophysical properties and energy systems" 9-10 September 2021, Rostock, Germany; 27) Proceedings of III international Agricultural, biological & life science conference AGBIOL, 1-3 September 2021, Edirne, Turkey; 28) 23rd ISI scientific and technical congress with international participation September 8-10, 2021, Gaziantep, Turkey; 29) XVIII Interstate conference "Thermoelectrics and their applications". ISCTA, 19-21 September 2021 Saint Petersburg, Russia:

The results were widely used in the process of teaching relevant subjects to the students of AzTU who are studying electronic engineering.

Based on the results of the research conducted on the subject of the dissertation, 59 works were published. 26 of them are scientific journal articles, 12 are conference materials, and 21 are theses of various level scientific conferences.

Name of the organization where the dissertation work was performed:

The dissertation work was carried out in the department of "Engineering physics and electronics" of Azerbaijan Technical University.

The structure and scope of the dissertation:

The dissertation consists of an introduction, 6 chapters, main results, a list of used literature and abbreviations. The dissertation consists of 333 pages of A4 format computer text and a bibliography of 327 titles and 445311 signs.

MAIN CONTENT OF THE DISSERTATION

The introduction reflects the relevance and degree of development of the topic, the purpose and tasks of the research, research methods, the main propositions defended, the scientific novelty of the research, the theoretical and practical significance, approval and application of the research. It also shows the importance of applying the work.

The introduction reflects the relevance of the topic, the purpose of the work, the issues raised and the main provisions for defense. It also shows the importance of applying the work.

The first chapter modern scientific literature was analyzed on the physico-chemical, crystallographic and electrophysical properties of indium tellurides, their application directions in electronic techniques of these compounds and the systems containing indium telluride.

A preliminary study of the scientific literature showed that indium telluride found relatively few applications compared to its

analogues. With this in mind, the second component that influences indium telluride is selected in such a way as to enhance the application of indium telluride as well as the scientific aspects. For example, recent studies show that InTe is close to being an effective thermoelectric material, which is why mainly high-thermoelectric components are added to the indium monotellurid. Or because the use of the In_2Te_3 combination is promising on the electronic media, the second components that affect it should be compounds that improve these properties.

In second chapter is methodical, namely, experimental equipment, principles of measurements in them, acquisition of complex compounds alloy in In_2Te_3 and InTe systems, physico-chemical, thermal physics, galvano- and thermomagnetic and also some other properties of measuring methods are described. At the end of the chapter, calculated prices of errors in experimental devices were presented.

In third chapter is devoted to the clarification of the nature of phase equilibrium in the semiconductor systems with the involvement of indium tellurides, the determination of new compounds and solid solutions, and the study of their physical and chemical properties. Here, 18 phase diagrams investigated by In_2Te_3 and InTe compounds are illuminated. Of these diagrams, nine refer to systems with In_2Te_3 and nine to InTe systems. Since the presence of one of the second components (CuCr_2Te_4) that interact with each other is questionable because of the literature data, the system by which this compound was formed was further investigated and the nature of the formation of this compound was determined by us. Thus, the number of phase diagrams established for the first time in the dissertation was 19 (18+1).

From the established phase diagrams it was found that, the reason for occurring the complex formation of a complex natural phase is the In_2Te_3 combination, as well as the phase transitions in the second component, the defective structure of the indium telluride, and organization of the compositions of the affective components from complex and various configuration elements. All In_2Te_3 integrated systems experience phase transitions that are characteristic

of this combination, however, here, the nature of phase transitions due to the influence of the second component is both eutectoid and peritectoid nature. The thermodynamic parameters of alloys in the investigated systems were calculated and solid solutions and compounds formation energies were found. Some nano-sized wire crystals were also obtained by conducting efficient work on crystallization technology of some solid solutions found on the basis of In_2Te_3 . The results from the first-time phase diagrams can be summarized as follows:

1. The **$\text{In}_2\text{Te}_3\text{-MnTe}_2$** system is non-quasibinary and it produces complex chemical interactions. The features of the system are explained by the fact that MnTe_2 is incongruently and its position in the In-Mn-Te concentration triangle. At a temperature of 300 K, solid solution area based In_2Te_3 with a limit of ~ 5 mol% MnTe_2 was found in the system.

2. The nature of the interaction in the **$\text{In}_2\text{Te}_3\text{-Ni}_3\text{Te}_4$** system was clarified, it was determined that the system was quasibinary, based on both starter components and the solubility of ~ 10 mol% In_2Te_3 and ~ 5 mol% Ni_3Te_4 was formed at boundaries 300 K. (Figure 1).

3. A physical-chemical analysis of the **$\text{In}_2\text{Te}_3\text{-CuInSe}_2$** system was carried out, the system was found to be quasibinary, and the presence of a limited solid-state solution based on both initial compounds was defined. Homogenous sites cover a concentration of ~ 4 mol% CuInSe_2 and ~ 3 mol% In_2Te_3 .

4. The **$\text{In}_2\text{Te}_3\text{-CuGaSe}_2$** system is quasibinary. On the basis of both constituents, solid solution areas were found that also their limit at room temperature is up to ~ 5 mol% based on In_2Te_3 and ~ 10 mol% on CuGaSe_2 basis.

5. The **$\text{In}_2\text{Te}_3\text{-Cd}_{0,9}\text{Zn}_{0,1}\text{Te}$** system is quasibinary, the phase diagram is eutectic type, at room temperature the solubility on side of In_2Te_3 is up to ~ 3 mol%, and the solution of In_2Te_3 on side of $\text{Cd}_{0,9}\text{Zn}_{0,1}\text{Te}$ is up to ~ 5 mol%. It has been found that, in the system the process of stratification occurs at $\sim 18\text{-}41$ mol% a concentration of $\text{Cd}_{0,9}\text{Zn}_{0,1}\text{Te}$ alloy from the primary components.

6. The **$\text{In}_2\text{Te}_3\text{-CuCr}_2\text{S}_4$** system is partially quasibinary. A solid solution area was detected based on both starter components. Their

limit at 300 K is up to 3 mol% on side of In_2Te_3 and 5 mol% on side of CuCr_2S_4 . From the calculations of thermodynamic parameters it was found that the strength of the chemical bond weakens when the CuCr_2S_4 compounds move to solid solutions obtained on its basis. The effect of the CuCr_2S_4 combination was found to decrease the temperature of the modification transitions in In_2Te_3 .

7. A study of the **$\text{In}_2\text{Te}_3\text{-Cu}_2\text{Ga}_4\text{Te}_7$** system has revealed that the system is quasibinary, and the In_2Te_3 modification transitions are occurring in the phase diagram as a eutectoid nature. In the system, a new congruent melting $\text{CuGa}_2\text{InTe}_5$ and a solid solution area are formed on the basis of both starter components. Liquidus curves of the established phase diagram are formed liquidus wings of the α -phase, which initially crystallized in the liquid phase, the new $\text{CuGa}_2\text{InTe}_5$ combination and γ -phase.

8. A study of the **$\text{In}_2\text{Te}_3\text{-Cu}_2\text{In}_4\text{Te}_7$** system revealed that in the system the CuIn_3Te_5 triple combination, which melts congruently at a ratio of 1:1 of the starter components, is formed. Also, there are limited solid solution areas on the basis of both components. Under the influence of $\text{Cu}_2\text{In}_4\text{Te}_7$, the phase transitions in In_2Te_3 are of a different nature, that is, the high-temperature modification transition is of the peritectoid nature and the low-temperature modification transition is eutectoid.

9. In the **$\text{In}_2\text{Te}_3\text{-CuZn}_2\text{InTe}_4$** system, solid solution areas were detected on the basis of both starter components. Their limit is in the compositions of 3 mol% $\text{CuZn}_2\text{InTe}_4$ and 10 mol% In_2Te_3 at 300 K. The two modification transitions specific to the In_2Te_3 combination also appear in this system as a peritectoid-type transformation.

10. From the phase diagram of the **$\text{InTe-Cr}_2\text{Te}_3$** system, it was revealed that, the system is quasi-stable. In the system the InCr_2Te_4 combination, which melts incongruently at a ratio of 1:1 of the starter components, is formed. The crystal lattice constants of this compound were calculated and found that it crystallizes in the tetragonal structure with a space group 14 / mcm. The presence of a solid solution area was detected on the basis of both starter components of the system.

11. The nature of the physico-chemical interaction between **InTe-CoTe₂** was clarified. Because CoTe₂ is an incongruent melting compound, the established phase diagram is also of a relatively complex nature. In general, the system is quasi-stable, based on the InTe combination, solid solution area with limit of up to 6 mol% was found.

12. Phase equilibrium has been investigated in the **InTe-TlGaTe₂** system and it has been determined that the InTe-TlGaTe₂ system is quasibinary and A new compound of TlGaInTe₃-containing congruent melting is formed in the system at a ratio of 1:1. It was determined that this compound crystallized in the tetragonal sychonia with cage constants $a = 8,437 \text{ \AA}$, $c = 6.92 \text{ \AA}$. While there is 3 mol% TlGaTe₂ solvent based on InTe, the solid solution area on the basis of TlGaTe₂ contains 5 mol% InTe (Figure 2.)

13. The **InTe-TlInSe₂** system is quasibinary and has a simple eutectic type. At room temperature, 6 mol% TlInSe₂ is soluble based on InTe, while the solid solution area contains 10 mol% InTe on the basis of TlInSe₂.

14. The **InTe-TlBiTe₂** system is partly quasibinary, which is due to the fact that the TlBiTe₂ compound has an incongruent (peritectic) melting nature. Unlike other systems with InTe, the process of phase formation here is relatively complex and a solid solution area is created on the basis of only the InTe component. The limit of this area in the room temperature is composed of ~3 mol% TlBiTe₂.

15. The **InTe-CuGaTe₂** system is quasibinary, and is eutectic type. While in the the system there is 3 mol% CuGaTe₂ solubility at room temperature based on InTe, CuGaTe₂ based solid solution contains 5 mol% of InTe.

16. The **InTe-Bi_{1.3}Sb_{0.7}Te₃** system is quasibinary. On the basis of InTe, a solid solution area with a boundary of ~2 mol% Bi_{1.3}Sb_{0.7}Te₃ was found. Stratification in liquid phase with 19-54 mol% Bi_{1.3}Sb_{0.7}Te₃ compounds has been detected in the system above 800 K, which can be attributed to the sharp differences between the densities and compositions of the primary components, based on the literature data.

17. In **InTe-CuCr₂Te₄** system the first crystallizing substance is the Cr₅Te₈ combination. However, starting at 1346 K, the system is undergoing crystallization of CuCr₂Te₄ combination and other phases. The presence of three-phase areas in the system to temperatures up to 903 K indicates that the system is quasi-stable nature, at the same time all compositions except the α -solid solution formed in the system are collapsed as a double-phase mixture (except for formed solid solution compositions based on InTe). InTe form a solid solution area in the system with a limit of up to ~2 mol% CuCr₂Te₄ at 300 K. 18. In order to clarify the existence of CuCr₂Te₄ in the InTe-CuCr₂Te₄ system, In addition, the nature of phase formation in the **CuTe-Cr₂Te₃** system has been investigated and it is shown that the incongruent melting CuCr₂Te₄ compounds are formed in the system at the temperature of ~1120° C. Along with this combination in the system, a solid solution area with phase and magnetic transitions based on the Cr₂Te₃ component and with the limit of ~3 mol% CuTe at the room temperature was also detected.

19. For the first time, the phase diagram of the **InTe-Cu₂ZnSnS₄** system was established and it was discovered that the system is quasibinary, and its phase diagram is of simple eutectic type. The coordinates of the eutectica are suitable for the 813 K temperature and a content of 25 mol% Cu₂ZnSnS₄. On based both starter components, solid solutions are formed and their boundaries at 300 K reach 2 mol% Cu₂ZnSnS₄ on side of InTe and 3 mol% InTe on side of Cu₂ZnSnS₄.

In order to explain the tendency of the In₂Te₃ combination and solid solution compounds on its basis to polymorphism, it should be taken into account that as a result of external influences (e.g., pressure, temperature, etc.), the crystal with defective structure becomes unstable (labile). As a result, changes occur in the distribution of atoms and defects and they either become regular or irregular. This case cause to the formation of both solid solution and polymorphism.

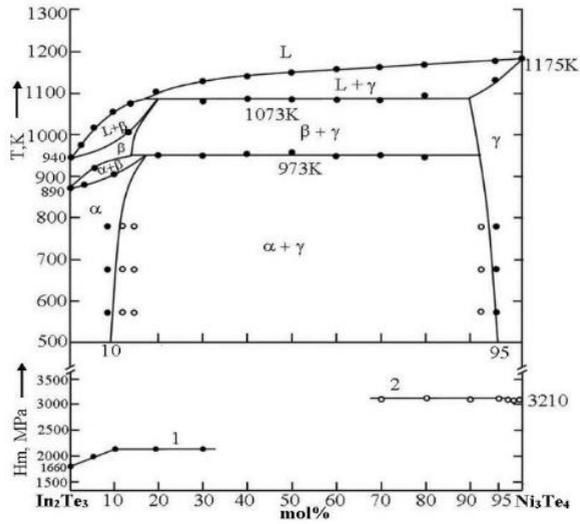


Figure 1. Phase diagram of In_2Te_3 - Ni_3Te_4

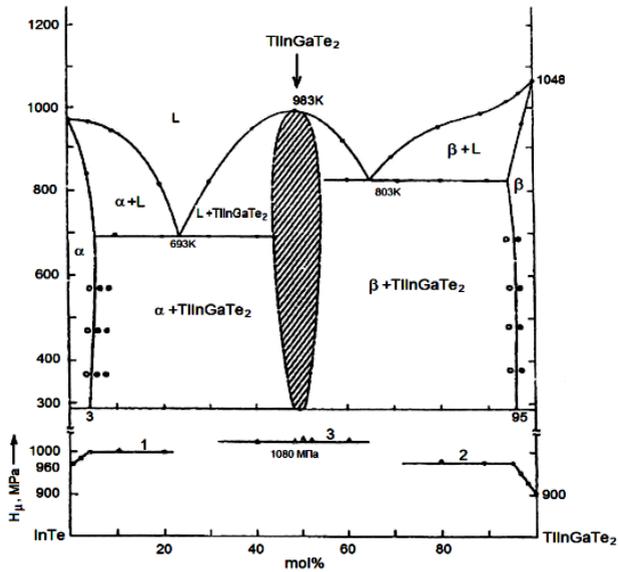


Figure 2. Phase diagram of InTe - TlGaTe_2

When the solid solution compounds were taken as the second component ($\text{Bi}_{1.3}\text{Sb}_{0.7}\text{Te}_3$ and $\text{Cd}_{0.9}\text{Zn}_{0.1}\text{Te}$, respectively), in the systems investigated by InTe and In_2Te_3 , in both of these systems, unlike other systems, areas of stratification (likvasiya) were found. Typically, such areas are formed during the physical and chemical interaction of components whose compositions and densities are sharply differentiated. The primary components of these two systems investigated are very different. On the other hand, when investigating the nature of the chemical bonding in solid solutions we have shown that the weakening of the chemical bond strength in solid solutions indicates that they are not a stable phase. Since such instability can also occur in solid solutions $\text{Cd}_{0.9}\text{Zn}_{0.1}\text{Te}$ and $\text{Bi}_{1.3}\text{Sb}_{0.7}\text{Te}_3$, the formation of unstable phases in their interaction with indium telluride is not excluded.

From the comparative analysis of the width of the solution areas boundaries in the systems we can conclude that in the direction of $\text{Cr} \rightarrow \text{Mn} \rightarrow \text{Ni}$, the solution area is expanding in the compositions of the second components added to the indium telluride. Most likely, the reason is that chromium has a more stable electron structure compared to other 3d-elements.

The thermodynamic functions of solid solution compositions and new compounds found in the studied semiconductor systems were calculated, and according to the results obtained, it has been defined that the compounds based on indium telluride are partially stable mixtures. The feature of the weakening of the chemical bond with the complicating of the compounds in the solid solutions was explained by the dependence of the phonon thermal conductivity on the microhardness.

Also, nano-sized wire-shaped crystals of $(\text{In}_2\text{Te}_3)_{1-x}(\text{Cu}_2\text{Ga}_4\text{Te}_7)_x$ solid solutions were obtained.

The fourth chapter summarizes the results of the investigation of heat and electric load transport mechanisms in solid solution crystals detected on the basis of In_2Te_3 and InTe compounds. The study of the thermal, physical, Galvano-, thermagnetic, and other properties of the obtained solid solution shows that scattering of charge carriers in samples is mainly due

to the additive atoms ionized at low temperatures, and the thermal dances of the Crystalline Cage at high temperatures. However, depending on the compositions, there are other mechanisms for electron scattering, such as scattering from polarized optical dances and acoustic phonons of the crystal cage.

Based on the In_2Te_3 inversion of thermo-e.m.f coefficient occurs in solid solutions combination by its decreasing, however, in solid solutions based on InTe , there is a sharp rise by increasing temperature. The reason for this change is that normalization of the crystalline cage with filling of vacancy type gaps in In_2Te_3 -based alloys while InTe -based solid solution alloys have a complex zone structure.

The thermal dependence of some thermal and physical and thermomagnetic parameters in $(\text{In}_2\text{Te}_3)_{1-x}(\text{MnTe}_2)_x$ solid solutions ($x=0,05$) has been investigated and it has been found that the heat transfer in the alloy occurs on complex multifonon and acoustic-optical mechanisms. At high temperatures, an additional phonon thermal resistance is formed in the solution of solid solution which is explained by the fact that the heat scattering is caused by point defects (vacancies). The addition of MnTe to In_2Te_3 results in a reduction of the width of the inhibition zone in $(\text{In}_2\text{Te}_3)_{1-x}(\text{MnTe}_2)_x$ solid solutions. In order to clarify the nature of the thermal conductivity in the investigated composition, parts should be calculated according to the phonons and electrons (According to Videman-France law $\alpha_{\text{el}}=L\sigma T$) and their temperature dependence should be analyzed. Phonon thermal resistance values were calculated according to the inverse values of α_{phonon} and its temperature dependence was established. It has been revealed that up to ~ 420 K temperature the thermal resistance of the crystal cage (W_f) has the dependence suitable for the three-phonon thermal conductivity which coincides qualitatively with theoretically calculated coefficient (W_0) of the quantity (Figure 3).

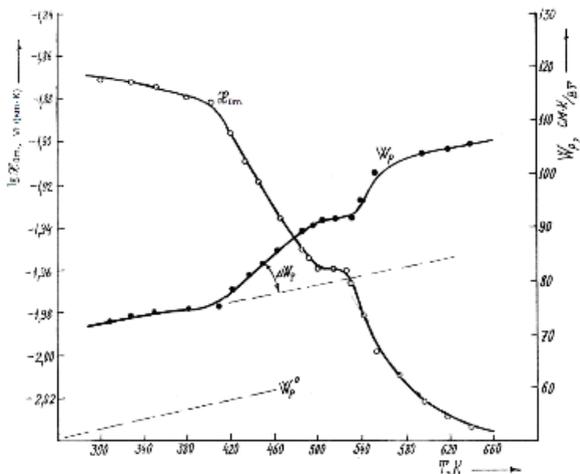


Figure 3. Total thermal conductivity (κ) and phonon thermal resistance (W_f) of solid solution alloy with $(\text{In}_2\text{Te}_3)_{0.95}(\text{MnTe}_2)_{0.05}$ composition

However, starting with the indicated temperature, including the temperature at which the thermal conductivity remains constant, an additional phonon thermal resistance (ΔW_f) is created in the sample. Apparently, the acoustic-optical heat transfer mechanism is being added to the process of three-phonon heat transfer at a temperature range of 420-500 K. Quantitatively, the number of such mechanisms can be estimated as $\Delta W = W_{\text{experiment}} - W_{\text{multiphonon}}$. Then up to 540 K the weakening of heat resistance is observed depending on the temperature. At higher than 540 K, a further increasing of additional phonon thermal resistance occurs in the temperature dependence of W_f . Calculation of the thermal resistance of the phonon by the Clemens formula $\kappa_f = cT^{-n}$ (where c is a constant quantity and describes the perfection of the crystal cage) showed that the value of n is $-(0,7 \div 0,32)$ in the studied solid solution alloy, that is, the three-phonon scattering mechanism dominates in the heat transfer. However, the heat transfer mechanism may also change that the temperature of such a change is also confirmed by the temperature dependence of the Nernst–Etingshausen coefficient (ε_y). It has been

known that the ε_y coefficient has a negative sign at low temperatures, but with increasing temperatures, the quantity is definitely reducing, and this quantity is also undergoing to inversion when the heat transfer mechanism changes in the sample. It has been defined that in $(\text{In}_2\text{Te}_3)_{1-x}(\text{Ni}_3\text{Te}_4)_x$ solid solutions, the electronic and phonon scattering mechanisms have a simpler nature than the temperature dependence of kinetic coefficients. It is determined by the temperature dependence of Hall mobility of the general heat conductivity and the charge carriers that in $(\text{In}_2\text{Te}_3)_{1-x}(\text{Ni}_3\text{Te}_4)_x$ solid solutions, the transport of the load occurs at low temperatures as a result of ionized additive atoms of charge carriers and at high temperatures due to scattering of the crystal cage from heat dances. The heat transfer varies according to the single-phonon scattering mechanism. In addition, no additional phonon thermal resistance occurs in these solid solution alloys. It has been determined from the temperature dependence of kinetic coefficients of $(\text{In}_2\text{Te}_3)_{1-x}(\text{Cd}_{0.9}\text{Zn}_{0.1}\text{Te})_x$ solid solution alloys that they have a complex nature of electron and phonon scattering mechanisms, which is due to the defect of the crystalline cage on the one hand and the large number of components in the composition on the other. The scattering of electrons in the samples is of a mobile nature. As for heat transfer, the three-phonon heat scattering mechanism is dominated by the formation of additional phonon heat resistance at high temperatures.

With the increase of temperature in the temperature dependence of the overall heat conductivity of $(\text{In}_2\text{Te}_3)_{1-x}(\text{Cd}_{0.9}\text{Zn}_{0.1}\text{Te})_x$ solid solution alloys the α_{um} has a change in accordance with the law of negative surface. However, there is a slight increase in the heat transfer from $\sim 700\div 800$ K. Usually, such an increase in semiconductor material is due to the formation of $\alpha_{\text{b-p}}$ bipolar heat transfer. However, the calculations showed that the portion of $\alpha_{\text{b-p}}$ quantity in the studied solid solutions was not significant. In the temperature dependence of the $(\text{In}_2\text{Te}_3)_{1-x}(\text{Cd}_{0.9}\text{Zn}_{0.1}\text{Te})_x$ alloys phonon heat resistance up to ~ 500 K, the phonon heat resistance increases steadily and qualitatively correlates with the theoretical estimated value (W_0) of this quantity. Further increase in temperature causes additional phonon heat resistance in

the samples. The addition of phonon heat resistance is an indication that the heat transfer in samples is due to acoustic-optical phonons. From the calculations it became clear that ~up to 573 K the change of W_f happens according to the $T^{0.3\pm 0.5}$ law. In other words, a three-phonon scattering mechanism plays an important role in the heat scattering for $(\text{In}_2\text{Te}_3)_{0.99}(\text{Cd}_{0.9}\text{Zn}_{0.1}\text{Te})_{0.01}$ content above 753 K.

The nature of electron scattering in semiconductor materials can be determined by the fact that the dimensionless Nernst-Ettingshausen coefficient (ε_y) is dependent on $\frac{HU_H}{c}$ quantity. If $\frac{HU_H}{c} > 1$ in the dependence of $\varepsilon_y \sim f\left(\frac{HU_H}{c}\right)$ then the dispersion becomes inelastic, however, in case of $\frac{HU_H}{c} < 1$, the dispersion becomes an elastic nature. It has been clear from the $\frac{\Delta\alpha}{\alpha}$ temperature dependence of Nernst-Ettingshausen coefficient and $\frac{\Delta\rho}{\rho}$ temperature dependence of magnetic resistance of $(\text{In}_2\text{Te}_3)_{0.97}(\text{Cd}_{0.9}\text{Zn}_{0.1}\text{Te})_{0.03}$ alloys, the change of sign of $\frac{\Delta\rho}{\rho}$ quantity occurs at ~473 K.

From the established dependence for the solids solution with $(\text{In}_2\text{Te}_3)_{0.97}(\text{Ni}_3\text{Te}_4)_{0.03}$ composition it was found that the value of $\frac{HU_H}{c}$ is greater than one. Namely, the dispersion of the carriers in the aforementioned solid solution is of a mobile nature. This hypothesis is also confirmed by the positive sign of $\frac{\Delta\rho}{\rho}$ quantity. It has been found that the nature of electron-phonon scattering in solid solutions of $(\text{InTe})_{1-x}(\text{CuZn}_2\text{InTe}_4)_x$ can be explained mainly by the processes of occupying gaps (vacancies) in the crystal cage occurring in the alloys in small substitutions. The transport phenomena here are on more simple mechanisms. the width of the thermal inhibition zones of the $(\text{InTe})_{1-x}(\text{Cr}_2\text{Te}_3)_x$ alloys was calculated according to the change of special electrical conductivity of solid solution alloys in the specific conductivity field. Addition of Cr_2Te_3 to the indium monotellurid results in a reduction of the inhibition zone. It appears that when a solid solution is formed the formation of heteropolar chemical bonds surpasses the formation of solid solutions.

In the temperature dependence of thermo-e.m.f. coefficient of $(\text{InTe})_{1-x}(\text{Cr}_2\text{Te}_3)_x$ solid solution alloys, at low temperatures (up to ~ 600 K), the thermal-e.m.f. coefficient, as in the case of semiconductors with a complex zone structure, has a steadily rise. (Figure 4). Thermo-e.m.f. coefficient and special electrical conductivity in this area of temperature are characterized by the following expressions:

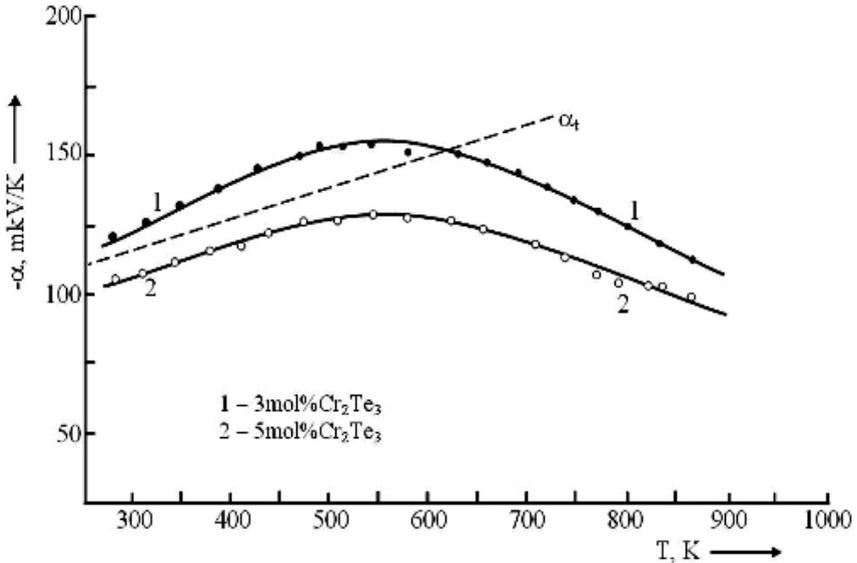


Figure 4. In the temperature dependence of thermo-e.m.f. coefficient of $(\text{InTe})_{1-x}(\text{Cr}_2\text{Te}_3)_x$ solid solution alloys

$$\alpha = \pm \frac{k}{e} \left[\frac{r+1}{r+2} \frac{F_{r+1}(\mu^*)}{F_r(\mu^*)} \right]$$

$$\sigma = \frac{16e^2 m^* \ell_0(\mu_0)}{h^3} F_{\frac{1}{2}}(\mu^*)$$

At high temperatures, thermo-e.m.f. coefficient is characterized by processes involving both types of charge carriers. In this case, the thermo-e.m.f. coefficient is expressed with the

$$\alpha = \frac{\alpha_p \sigma_p + \alpha_n \sigma_n}{\sigma_p + \sigma_n}$$

formula. The reason for the decrease in thermoelectric coefficient at high temperatures is the activation of the third type of charge carriers in the energetic strip, namely the heavier masses. In this situation, the dependence of $\alpha \sim f(T)$ will be determined by the

$$\alpha = \frac{\alpha_p \sigma_p + \alpha_n \sigma_n - \alpha_{a\ddot{g}tr} \sigma_{a\ddot{g}tr}}{\sigma_p + \sigma_n - \sigma_{a\ddot{g}tr}}$$
 expression.

It is evident from the temperature dependence of the Hall mobility of charge carriers in solid solution compositions, there is already a change in the dispersion mechanism starting at room temperature. Mobility curves tend to weak decline at high temperatures, passing the spread maximum. At high temperatures, the mobility changes according to the $T^{-(0,85-0,95)}$ law. This shows charge carriers scatter from ionized additive atoms. It should be noted that analogical scattering mechanism is a characteristic of pure indium monotellurid. The temperature dependences of the total heat transfer of $(\text{InTe})_{1-x}(\text{Cr}_2\text{Te}_3)_x$ alloys have a negative surface variation of up to ~ 673 K. In subsequent rise in temperature, the thermal conductivity tends to weakly rise. It has been clear from the calculation of α_{b-p} component that the presence of such a mechanism in the studied compounds of solid solution is insignificant.

The temperature dependence of the phonon heat resistance has been established to determine the presence of other mechanisms in heat transfer. Calculations showed that $T^{-0,04}$ law prevails in the process of heat transfer in the low temperature range (up to 500 K).

When the temperature varies in the range of 500-773 K, the $T^{0,25}$ law dominates the thermal conductivity. This indicates that heat dissipation at low temperatures occurs by a one-phonon mechanism. However, according to the values of the upper quantity, it can be concluded that multi-phonon processes begin in the alloys, and the presence of another mechanism in the heat transfer, the scattering mechanism from the point imperfection, is not excluded.

The temperature dependence of thermoelectric parameters of $(\text{InTe})_{1-x}(\text{Cr}_2\text{Te}_3)_x$ solid solutions alloys showed that at ~ 700 K the alloys have an accepted effectiveness for thermoelectric materials,

which ($Z_{700}=0,52 \cdot 10^{-3} \text{ K}^{-1}$) this indicator makes them promising for the preparation of thermoelectric power circuits.

The study of the temperature dependence of heat transfer and Hall mobility of charge carriers in $(\text{InTe})_{1-x}(\text{TlGaTe})_x$ solid solution crystals revealed that heat transfer in both pure InTe and solid solution crystals occurs under a single-phonon mechanism. At high temperatures, complex mechanisms dominate in the heat transfer. The evident that the thermo-e.m.f. coefficients of the samples vary depending on the temperature uncovered that, where the thermo-e.m.f coefficient, as in the case of semiconductors with complex zone structures, has a tendency for steadily sharp rise first and then decrease passing from the maximum.

In order to clarify the heat transfer mechanism in the studied crystals, the constituents of the total heat transfer were calculated and analyzed more extensively. Here the $\alpha_{b-p}=2L_0\sigma T \left(\frac{\Delta E}{4kT} + 1\right)^2$ formula is mainly used. It was evident from the temperature dependence of the InTe combination and the thermal conductivity of $(\text{InTe})_{1-x}(\text{TlGaTe}_2)_x$ solid solution crystals due to electrons that the rise in temperature leads to an increase in the thermal conductivity due to electrons. Apparently, the role of electrons in thermal conductivity at high temperatures is remarkable. However, in our opinion, phonons play a key role in the heat transfer in crystals. In the samples, with a rise in the temperature, the heat resistance of the crystal cage increases. However, if this increase is steadily according to the theoretically calculated value (W_0) of thermal resistance in pure InTe, in the samples containing TlGaTe_2 such compatibility is paid only at low temperatures ($\sim 500 \text{ K}$). The subsequent rise in temperature is accompanied by an additional phonon thermal resistance (ΔW_f). In the first composition of the solid solution (0,5 mol% TlGaTe_2), the value of the additional phonon heat resistance is small. In a sample with a higher content of the second component, the value of phonon heat resistance is greater.

It has been found that the heat transfer in the sample with $(\text{InTe})_{0,995}(\text{TlGaTe}_2)_{0,005}$ composition occurs under $T^{-0,01}$ law, and in the sample with $(\text{InTe})_{0,99}(\text{TlGaTe}_2)_{0,01}$ composition, up to 500 K

under $T^{-0,05}$ law and at higher temperatures under $T^{-0,16}$ law. That is, while single-phonon thermal phenomena prevail in InTe, the mechanism can be changed in solid solution compositions to reach the multi-phonon thermal scattering mechanism, and the scattering corresponding to the "ejection" mechanism also finds its place in the examples shown.

Since the calculations on bipolar heat transfer do not yield satisfactory results, it is possible to conclude that the investigated solid solutions have other mechanisms of thermal conductivity at high temperatures. At high temperatures in $A^{III}B^{VI}$ -type compounds and alloys based on them, the mechanism of dislocation is weakened, instead, the process of increasing in the heat transfer occurs due to the strengthen of the activation energies of the electronic transitions. In our opinion, very small sizes of GaTe compounds are formed in solid solutions, which also affect the overall heat transfer by the mechanisms. In our opinion, very small associate with GaTe compounds are formed in $(InTe)_{1-x}(TlGaTe_2)_x$ solid solutions, which also affect the overall heat transfer by the mechanisms shown. One of the reasons for the increase in heat transfer at high temperatures is the thermal conductivity caused by excitons, which the mechanism can also be formed in $(InTe)_{1-x}(TlGaTe_2)_x$ solid solution crystals. It was found that $(InTe)_{1-x}(TlBiTe_2)_x$ solid solution alloys have high strength of thermoelectric efficiency ($\alpha^2\sigma$) at 700 K.

It has also been detected that heat transfer in $(InTe)_{1-x}(Cu_2ZnSnS_4)_x$ solid solution alloys is carried out in accordance with a single-phonon mechanism. Solid solution alloy with $(InTe)_{0,98}(Cu_2ZnSnS_4)_{0,02}$ content has high thermoelectric efficiency ($Z_{700-800K}=1,5 \cdot 10^{-3} K^{-1}$) and can be used in the production of thermoelectric power generators. It turned out that the addition of Cu_2ZnSnS_4 cause to increase the width of InTe prohibition area and thermo-e.m.f coefficient. The reason why the content of $(InTe)_{0,98}(Cu_2ZnSnS_4)_{0,02}$ has a high value of Z is because of its low values in heat conductivity. The main reason for this is the decrease in thermal conductivity due to the rise in phonon-phonon anharmonism at high temperatures ($\sim 800 K-d\theta$). The coefficient of anharmonicity (Grüneisen parameter) at 800 K was calculated for

$(\text{InTe})_{0,98x}(\text{Cu}_2\text{ZnSnS}_4)_{0,02}$ content with high thermoelectric efficiency. From the calculations it was found that $\gamma_{800\text{K}}=2,7$ for the $(\text{InTe})_{0,98}(\text{Cu}_2\text{ZnSnS}_4)_{0,02}$ compound. This price indicates a high level of anharmonicity in the composition.

In the fifth chapter the results obtained from the study of the temperature dependence of the $(\text{Cr}_2\text{Te}_3)_{1-x}(\text{In}_2\text{Te}_3)_x(\text{CuInSe}_2)_{1-x}(\text{In}_2\text{Te}_3)_x$, $(\text{Cu}_2\text{GaTe}_7)_{1-x}(\text{In}_2\text{Te}_3)_x$, $(\text{CuCr}_2\text{Te}_4)_{0,99}(\text{InTe})_{0,01}$ solid solutions and of the kinetic coefficient of the new $\text{CuGa}_2\text{InTe}_5$ compound in the studied systems show that some of them have high thermoelectric efficiency but also have some abnormalities in properties. The reason for the different types of transport mechanisms discovered is the complexity of the composition on the one hand, and the unevenness of the zone structure on the other.

From the study of thermoelectric parameters of the alloy containing $x = 0.01$ in $(\text{Cr}_2\text{Te}_3)_{1-x}(\text{In}_2\text{Te}_3)_x$ solid solutions, it has been defined that the composition has a high thermoelectric efficiency ($Z_{600}=1,18 \cdot 10^{-3} \text{ K}^{-1}$) at high temperatures.

The temperature dependence of $(\text{Cr}_2\text{Te}_3)_{0,99}(\text{In}_2\text{Te}_3)_{0,01}$ content and special electrical conductivity of the $(\text{Cr}_2\text{Te}_3)_{0,99}(\text{CuTe})_{0,01}$ solid solution found in the auxiliary $\text{Cr}_2\text{Te}_3\text{-CuTe}$ system, of thermo-e.m.f coefficient and total heat transfer has been investigated, comparative analysis has been carried out by calculating their thermoelectric efficiency values. The decrease in the electrical conductivity at low temperatures can be thought of as the result of the effect of asymmetric distribution of the 3d elements of electron density in the crystal field around the ionized particles. At high concentrations of 3d elements or in the case of excitation of crystals, 3d-wave functions can partially overlap and eventually create narrow, incomplete 3d-zones that also prevent transportation of electrical loads. In the subsequent rise of temperature, the degree of overlapping of wave functions are getting weaker, as a result, both incomplete narrow stripes and other additive subzones in the energetic zone begin to participate in the electrical load. A special conductive field is created above 470 K where the price of width of the thermal prohibition zone calculated from this area is $\sim 0,28 \text{ eV}$.

Thermo.e.m.f. coefficient of the alloy increases in the whole measurement range, and the overall heat transfer reduces. The reduction of the heat transfer with increasing temperature, the occurrence of normal phonon phenomena in the sample and the higher value of Z than a unit at 600 K indicates that this solid solution alloy is promising for the preparation of thermoelectric energy converters.

The search for promising thermoelectric materials was also carried out in $\text{Cr}_2\text{Te}_3\text{-CuTe}$ system in the solid solution components found on the basis of Cr_2Te_3 . The value of thermoelectric efficiency coefficient of $(\text{Cr}_2\text{Te}_3)_{0,99}(\text{CuTe})_{0,01}$ composition was calculated at different temperatures and found that at 500 K, $Z=0,51 \cdot 10^{-3} \text{ K}^{-1}$, and at 800 K, $Z=0,64 \cdot 10^{-3} \text{ K}^{-1}$. It was detected that these prices are much smaller than the prices of the same parameter of $(\text{Cr}_2\text{Te}_3)_{0,99}(\text{In}_2\text{Te}_3)_{0,01}$ solid solution.

In $(\text{CuInSe}_2)_{1-x}(\text{In}_2\text{Te}_3)_x$ alloys, special electrical conductivity, thermo.e.m.f. coefficient, the Hall mobility of charge carriers, total thermal conductivity and the temperature dependence of thermoelectric efficiency were investigated, and certain anomalous features were found in these dependencies. Hall mobility increases up to $\sim 540 \text{ K}$ depending on the temperature and tends to decrease after crossing an area of mixed scattering. The price of scattering mechanism of Hall mobility in the field of growth was $T^{3.5}$. Getting of the high rate of quantification characterizing the mechanism of free carriers scattering is feature of highly resistant materials, and here, the existing irregularities of the crystalline structure leads to additional scattering. That is, there are semiconductor materials in which the mobility of the carriers are it is not big and the average length of the free run is smaller than that of the crystal cage constant. In this case, the carriers can jump from one elementary cage to another. Since the frequency of such movements is characterized by $e^{-\frac{\Delta E}{kT}}$ quantification, the mobility is also defined by $U_H \sim e^{-\frac{\Delta E}{kT}}$. Indirectly, quantification reflecting the scattering mechanism in such semiconductors is large. The compositions we investigate also have a certain irregularity, as they are polycrystalline, as a result, they may

have additional sources of scattering. Calculations for $(\text{CuInSe}_2)_{0,99}(\text{In}_2\text{Te}_3)_{0,01}$ composition showed that with increasing temperatures, low Z values began to rise, which could also be considered satisfactory for thermoelements.

The temperature dependences of the total heat transfer coefficient of $(\text{Cu}_2\text{Ga}_4\text{Te}_7)_{0,995}(\text{In}_2\text{Te}_3)_{0,005}$ and $(\text{Cu}_2\text{Ga}_4\text{Te}_7)_{0,99}(\text{In}_2\text{Te}_3)_{0,01}$ solid solution alloys showed that where the heat transfer occurs by a three-phonon scattering mechanism. Given the fact that the bipolar and photon-mechanical heat transducers in the samples studied were almost non-existent, taking the values of α_{b-p} and α_{hot} equal to zero, the phonon heat transfer rates were calculated based on of $\alpha_{\text{fon}} = \alpha_{\text{com.}} - \alpha_{\text{elec.}}$ and the temperature dependence of the phonon

heat resistance was established according to $\frac{1}{\alpha_{\text{fon}}}$. In both investigated solid solution alloys, the thermal conductivity changes with the temperature in accordance with $T^{0,1}$ law. This change indicates that heat is transported by a three-phonon mechanism. However, starting at ~ 550 K, the phonon thermal resistance starts to increase more strongly, and additional phonon thermal resistance (ΔW_f) occurs in the samples. In this time, heat transfer is subject to the $T^{0,3}$ law.

The temperature dependence of the kinetic coefficients of $(\text{Cu}_2\text{GaTe}_7)_{1-x}(\text{In}_2\text{Te}_3)_x$ solid solution alloys is evident that the electron scattering at low temperatures is mainly due to the ionization centers of the additive atoms and at high temperatures the thermal dances of the crystalline cage. The phonon mechanisms in the samples are mainly consistent with the single-phonon collision laws. The emergence of phonon thermal resistance at high temperatures indicates that the phonon scattering results from vacancy type defects in the crystalline cage.

The thermoelectric efficiency of the alloy with $(\text{Cu}_2\text{Ga}_4\text{Te}_7)_{0,95}(\text{In}_2\text{Te}_3)_{0,05}$ comparison was calculated. It was found that at 700 K, the value of the thermoelectric efficiency of this compound was $Z = 0,5 \cdot 10^{-3} \text{K}^{-1}$.

It has been made clear that the anomaly encountered in the case of charge carrier phenomena in $(\text{CuCr}_2\text{Te}_4)_{0,99}(\text{InTe})_{0,01}$ solid solution

alloy is associated with the complexity of zone structure of alloy on the one hand and with an increase in effective mass on the other hand. The studied compound has high thermoelectric efficiency ($Z_{700K}=2,0 \cdot 10^{-3} \text{ K}^{-1}$) and can be used in the production of thermoelectric power converters operating at medium temperature intervals (Figure 5).

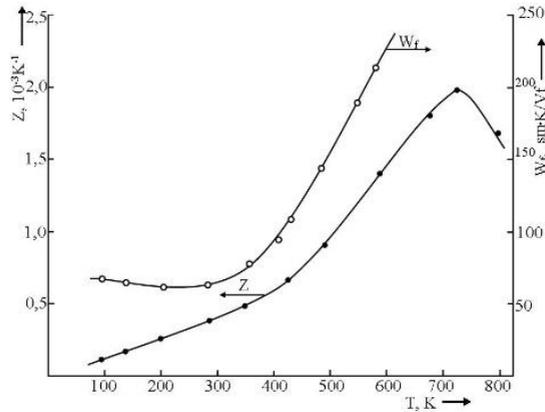


Figure 5. Temperature dependence of phonon thermal resistance (Wf) and thermoelectric efficiency coefficient (Z) of $(\text{CuCr}_2\text{Te}_4)_{0,99}(\text{InTe})_{0,01}$ solid solution alloy

It has been shown that the dependence of $\lg \sigma \sim f\left(\frac{10^3}{T, \text{K}}\right)$ are of a semi-metallicity nature. Already special conductive area starts in the sample from room temperature and the process of increasing electrical conductivity continues. It was found that the width of the thermal prohibition zone of the content is $\Delta E_g=0,32 \text{ eV}$. Thermo-e.m.f. coefficient increases from starting the liquid nitrogen temperature. Its relaxation occurs above $\sim 500 \text{ K}$. The increase in thermo-e.m.f. is characteristic of spinel structure ferromagnetic semiconductor materials. This anomalous change can be attributed to both the complexity of the zone structure and the growth of the effective mass.

At liquid nitrogen temperatures, the Hol mobility of the sample varies according to the law of $\sim T^{-1,2}$. That is, carriers here

are content with just single-phonon collisions. During the rise of temperature, the scattering of the carriers is subject to the law of $\sim T^{-1,9}$, where the collision results in a three-phonon scattering. The temperature dependence of the total heat conductivity of the compound and of its part on the basis of electrons indicated that the total heat transfer occurs at the liquid nitrogen temperature and begins to decrease after reaching room temperature. Such a change is characteristic of copper halogenogenic compounds. As the temperature rises, the ant coefficient grows. Apparently, the high thermal conductivity for the electrons is a result of the presence of too many atoms (electrons) at the core of the crystal. Thus, from the anomalies observed in the temperature dependence of the kinetic coefficient of $(\text{CuCr}_2\text{Te}_4)_{0,99}(\text{InTe})_{0,01}$ content, first of all, it can be noted that the thermal coefficients increase with respect to the temperature, which the case is usually typical of semiconductor materials with complex zone structure. The properties show that the investigated compound also has a similar zone structure. Such materials have an light and heavy type effective mass, and the increasing of thermo-e.m.f. with temperature is due to the effective mass. In the present study, the value of effective mass was calculated and its temperature dependence schedule was established. It has been brought into clear that in case of low temperatures (e.g. at 160 K), $\frac{m^*}{m_0} = 0,26$, at high temperatures (e.g at 700 K), $\frac{m^*}{m_0} = 1,17$. From the temperature dependence of the kinetic coefficient of the discovered $\text{CuGa}_2\text{InTe}_5$ combination, it was found that electrical loads and heat transfer occur through several mechanisms. The reason for the different types of transport mechanisms being identified is multi-component composition from the one aspect, and the complexity of the zone structure from the other. Temperature dependence of the electrical conductivity of combination is semi-metallicity nature. Startin from the temperature of ~ 413 K, there has been a sharp increase in electrical conductivity, which is an indication of the formation of special conductive area. Calculated the value of width of the thermal

prohibition zone was $\sim 0,88$ eV. Thermo-e.m.f. coefficient has a linear rise up to ~ 473 K depending on the temperature dependence of the thermo-e.m.f. coefficient. Then, $\alpha \sim f(T)$ dependence tends to decrease strongly in special conductive area, crossing from the maximum. The sign of α was negative for the entire temperature range measured.

It has been known from the temperature dependence of the lengthwise Hall mobility of carriers (U_H) and of the Nernst-Ettingshausen coefficient (ε_y) that the mobility changes up to ~ 400 K according to the law of $T^{1,5}$. Dependence of $\lg U_H \sim f(\lg T)$ crosses from the maximum at ~ 417 K and then begins to decrease on the point of the law of $T^{-3,5}$. The maximum dependence indicates the presence of carriers dispersed from polar optical dances. Crossing of the dependence from the maximum indicates the presence of carriers scattered from polar optical dances. At the mentioned temperature, ε_y quantification is also exposed to inversion. Up to the temperature of ~ 653 K, α_{tot} coefficient is changed by a negative surface law, which also indicates the occurrence of normal phonon phenomena in the combination. However, starting from ~ 653 K, the total thermal conductivity tends to increase. In order to clarify the issue, the quantitative role of electronic, phonon and bipolar heat transfer in the thermal conductivity of the compound was evaluated.

Due to the temperature dependence of the phonon heat resistance, it was found that the heat transfer of the studied compound varies with the law of $\sim T^{-0,32}$. This factor indicates that the heat transfer occurs through a three-phonon mechanism. The presence of three-phonon scattering in thermal conductivity is also proved by the variation of conductivity at high temperatures according to the $T^{-3,5}$ law. Apparently, this mechanism is dominant up to ~ 653 K as there is an increase in total heat transfer after this temperature. It has been defined that at high temperatures α_{b-p} increases strongly. This shows its great influence on the total heat transfer (Figure 6).

The negative sign of $\frac{\Delta\rho}{\rho}$ indicates that the mobility of carriers in the combination are small, while the negative sign is an indicator of the non-elastic nature of the scattering of carriers. Thus, summarizing the results of Chapter V, we can conclude that most of the investigated solid solution alloys and the kinetic coefficient of the new quaternary compounds show themselves as complex semiconductor materials with complex zone structure, depending on the temperature. Although these solid solutions were created based on the compounds that are considered promising for solar energy converters (e.g., CuInSe_2) and magnetic techniques (CuCr_2Te_4), their thermoelectric efficiency has been high. For this reason, most of the solid solution alloys studied can be used as a positive and negative leverage of thermoelement in the production of thermogenerators as effective thermoelectric materials.

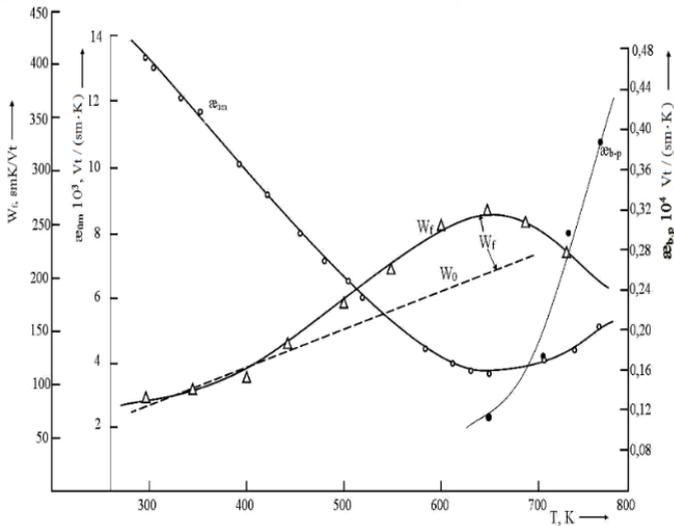


Figure 6. Temperature dependence of total thermal conductivity (α_{tot}), phonon thermal resistance (W_f) and bipolar thermal conductivity ($\alpha_{tot.}$) of new compound $\text{CuGa}_2\text{InTe}_5$.

In the sixth chapter presents the results obtained from the study of the synthesized crystals and by using their thin layers the

creation of solid-state heterocycles, thermoelectric energy converters and creation of solar battery elements, their application parameters and basic characteristics. The thin layers of InTe combination, solid solution alloys based on the InTe and In₂Te₃ compound, as well as triple compounds containing indium telluride were obtained and investigated by the "hot wall" option of thermal evaporation. Teterocyclic thin sheets with n-InTe/p-TlGaTe₂ structure were created, its photoelectric, volt-ampere and other characteristics were studied, an energetic diagram was established. It has been shown that at low voltage values, the flowing of current in the heterocyclic is determined by the equilibrium conductivity. It was determined that the injection current volume of the n-InTe layer is limited by the space charges. It is shown here that the exponential distribution of local conditions in the forbidden zone is the result of tunneling of the main transporters from the p-TlGaTe₂ layer to the epitaxial n-InTe layer. In practice, light beams are affected by the semiconductor side of the barrier zone. In practice, this was influenced by the semiconductor with a large width of the prohibition zone and with light beams.

Because it is no exception that in n-InTe/TlGaTe₂ heterocycles created by us the process that is related to the recombination of electron-hole pairs, and what is known in the literature as a "window effect" cause to photoresponse growth, the structure was illuminated on the side of p-TlGaTe₂ and the spectral characteristics were studied. Heterocyclic voltage was also applied when photoconductivity was measured. It has been known that as the value of the applied voltage increases, the photosensitivity grows. The maximum is found in spectral dependence in each voltage value. The maximum in characteristics corresponds to a wavelength of ~0.93 μm. However, the width of the material prohibition zone was calculated using the value of 1.05 μm of the formed spectral damping after the maximum. In this case the value of ~1.18 eV was obtained for the width of the prohibited zone, which aligns qualitatively with the energetic parameter of the TlGaTe₂ compound. The maximum photoconductivity value

shows that the created heterocyclic n-InTe/p-TlGaTe₂ structure can be used as a sensitive recording device in the near infrared range. The VAX of heterocyclic with n-InTe/p-TlGaTe₂ structure was measured at room temperature. Because omic contacts are from indium, it has not been possible to investigate VAX at higher temperatures. The energetic diagram of the heterocyclic, based on the model proposed in the literature, has been established without considering the surface electrical conditions. The diagram is based on the literature estimates of the energy parameters of InTe and TlGaTe₂ compounds. Some of the data is derived from the research in this case. Fermi level energy is assumed to be equal to the activation energy of the additives found in the previous paragraphs of the dissertation E_F .

A heterocyclic with p-InTe / n-TlInSe₂ structure was created, its volt-ampere, volt-farad and other characteristics were investigated, an energetic diagram was established. It has been shown that the simple physico-chemical interaction between InTe and TlInSe₂ compounds reveals itself in heterocyclic. Thus, the formation of thin layer with an additional high-resistance found in n-In₂Te₃/p-Cu₂Ga₄Te₇ heterocyclic does not occur in this heterocyclic. The VFX of heterocyclic was found to be linear, and it was defined that $U_d=0,57V$, based on $C^2 \sim f(U)$ dependence. It has been shown that the transfer of active centers from recombination nature to dispersion nature is not excluded in heterocyclic contact areas. It turned out that heterocyclic has a small adjustment coefficient ($k=3\div 8$). Release (transmission) voltage is realized when a positive polarity external sliding from n-TlInSe₂ is applied to base. The dark volt-ampere characteristics are symmetric in small voltage fields. This indicates that at low voltages the current is determined by balanced conductivity rather than by injection processes. However, the presence of injection processes is not excluded here. The exponential part of the VAX, covering the area of voltage $\sim 0.5-1.5 V$, corresponds qualitatively with the $I = I_0 \exp\left(\frac{eV}{\beta kT}\right)$ expression for the case of $\beta = 1,2-1,4$. This shows that in the field of spatial loads, in the heterocyclic

generation-recombination processes dominate. The found value of the current voltage in discontinuity from the linear part of the VAX was $U_d = 0.58$ V. At the higher values than the voltage, the linear field of VAX is characterized by the expression $I = BU^m$, where B is the proportionality ratio. Those having a degree indicator gets the values of $m = 1.6-1.8$. According to the literature data, this dependence may be due to the restriction of the injection current spatial loads of exponential distribution of local levels of InTe thin layer in the prohibition zone. Based on this, it is assumed that the main carriers from the n-TlInSe₂ layer are directly tuned to the local levels of the epitaxial layer of InTe and subsequently thermally activated to the valence zone. This event takes place in the $U < U_d$ state. Current flux above U_d voltage is regulated by spatial loads in the InTe layer. In the opposite direction, the heterocyclic VAX, which is created at relatively low voltage levels ($U \leq 1.5$ V), is subject to the linear law. At high values of reverse voltage, weak perforations are observed, which indicates the change of the reverse current according to the tunneling mechanism. In the direction of release, the saturation dark current at defined at zero voltage from the linear field of the VAX is not greater than the 10^{-6} A/sm² value, indicating the permeability holes involved in the conductivity process are not too high.

According to the volt-farad dependence of the heterocyclic generated, it was found that $U_d = 0.75$ V. An energetic diagram of the heterocyclic was created, taking into account the ionization potential and the electronegativity values of the contact components. Thermoelement structures was prepared for thermoelectric converters with the use of solid solutions and new compounds with synthesized and high thermoelectric efficiency and their basic parameters were studied. To keep the p- and n- arms of the thermoelement in the efficient contact, simple eutectic constituents were selected from the phase diagrams and their use as commutation sheets has been identified. The construction of the Peltier element was designed using high thermoelectric efficiency of $(\text{Bi}_{1.3}\text{Sb}_{0.7}\text{Te}_3)_{0.99}(\text{InTe})_{0.01}$ content and the scientific basis of principles of strengthening weak signals was developed by its use.

For this purpose, it has been suggested that the element used as a thermosistor in an electric circuit is made of alloy with $(\text{In}_2\text{Te}_3)_{0,95}(\text{In}_3\text{Te}_4)_{0,05}$ content. The proposed thermoelement structures are considered for thermogenerators operating at moderate temperature ranges. At the same time materials used in thermoelectric coolers (including heaters) were also obtained. These are $(\text{Bi}_{1,3}\text{Sb}_{0,7}\text{Te}_3)_{1-x}(\text{InTe})_x$ solid solution alloys found in $\text{InTe-Bi}_{1,3}\text{Sb}_{0,7}\text{Te}_3$. It is recommended that the p-arm of the Peltier element which is used in practice, be prepared from the $(\text{Bi}_{1,3}\text{Sb}_{0,7}\text{Te}_3)_{0,99}(\text{InTe})_{0,001}$ content, and the n-arm is made of $(\text{Bi}_2\text{Te}_3)_{0,99}(\text{TlInTe}_2)_{0,01}$ content. The circuit with which the Peltier element is connected also includes an e.m.f source and a load resistance. The heat released in the element can be characterized by the $Q=\varepsilon W$ expression where ε corresponds to the cold (ε_S) or heat (ε_0) ratios. When the temperature differences in thermoelement are not significant, $\varepsilon=\varepsilon_S=\varepsilon_0$. It can be written for the ε value based on literature:

$$\varepsilon = \frac{T}{\Delta T_m} f(Z), \quad (1)$$

where T is the temperature of the connecting plate made of cobalt, ΔT_m is the temperature difference in thermoelement, and Z is the thermoelectric efficiency. If $\Delta T = 1$, it is accepted $f(Z) \approx 0,2 = 0.2$ for modern thermoelements. According to the expression (1) $\varepsilon \approx 60$, that is, the amount of heat released on the connecting Co plate and its R_{load} resistance will be 60 times greater than the W power assigned to the input of the scheme. At a fairly high temperature resistance coefficient (TRC) of thermistor, the signal at the output of the circuit will be too larger than the signal at the input. The altering of output voltage (U_{out}) as a result of thermistor temperature changes are as follows:

$$U_{\text{out}} = \frac{ER}{(R_T + R)^2} \frac{dR_T}{dT} \Delta T_m \quad (2)$$

Given the value of T_m in this expression, then we can find the reinforcement ratio according to the voltage:

$$\beta_m = \frac{\Delta U_{\text{ctx}}}{\Delta U_{\text{gir}}} = \frac{1}{\alpha} \frac{ZT}{1+ZT} \frac{ER}{(R_T + R)^2} \frac{dR_T}{dT}. \quad (3)$$

If the released temperature in the R_T thermistor is taken into account, then the difference in the ΔT temperatures that occur will be smaller or larger than ΔT_m (which depends on the heat dissipation or absorption of the thermoelement at the junction). In this case it is possible to write:

$$\beta' = \beta_m \frac{\Delta T}{\Delta T_m}. \quad (4)$$

From this expression we can conclude that sufficient growth of the reinforcement ratio is achieved by a positive opposite connection during heat dissipation and that under certain conditions the generation occurs. When calculating the reinforcement ratio (γ) according to the power, it is not possible to take into account the heat released in the R_T thermistor. It can be assumed that $W_{R_T} = W_R = W$ the deviations of power is $\Delta W = \frac{1}{2}W$. Here ΔW is considered as a load for thermoelement:

$$\Delta W = \alpha IT - \varkappa \Delta T. \quad (5)$$

Since $\alpha IT = \varkappa \Delta T_m$, we can write that,

$$\begin{aligned} \Delta W &= \varkappa (\Delta T_m - \Delta T) \\ \gamma &= \frac{\Delta W_{out}}{\Delta W_{in}} = \frac{\varkappa (\Delta T_m - \Delta T)}{R_T I^2 + \alpha I \Delta T}. \end{aligned} \quad (6)$$

In the (6) expression if we show with $I = \frac{\varkappa}{\alpha T} \Delta T_m$ v $\frac{\Delta T}{\Delta T_m} = \theta$, it can be written by making simple transformations,

$$\gamma = \frac{1}{2} \frac{T}{\Delta T_m} ZT \frac{1-\theta}{1+ZT\theta} \quad (7)$$

In the case mentioned above, the Peltier heat and Coul heat had the opposite sign. If this temperatures are accumulated, then $\Delta T > \Delta T_m$. That is to write:

$$\gamma = \frac{1}{2} \frac{T}{\Delta T_m} ZT \frac{\theta-1}{1+ZT\theta}. \quad (8)$$

The analysis of expressions (3) and (8) shows that using this method can achieve reinforce in 10^3 - 10^4 compiled based on voltage and power.

Based on the conversion effect of $(\text{In}_2\text{Te}_3)_{0,97}(\text{MnTe}_2)_{0,03}$ content of VAX, a thin-film electronic key was developed, its signal conversion time, conversion potential, size of clock tact,

geometric dimensions of the active layer and other application parameters were calculated.

Solar element with Ni-SnO₂/p-(CuInS₂)_{0,99}(In₂Te₃)_{0,01}/n-TlInSe₂ structure was prepared and its application parameters were studied. For this purpose, photoelectric properties of (CuInS₂)_{0,99}(In₂Te₃)_{0,01} solid solutions and of TlInSe₂ compounds have been investigated separately and it was discovered that they were photovoltaic materials with high photosensitivity. Initially, single crystals of semiconductor materials of the solar element were obtained, then thin layers were precipitate on the K-208 type glass, taken as a planche by the technology of "hot wall". It should be noted that the K-208 glass is a special pure glass that its surface is coated with SnO₂ thin conductive sheets. Thickness of the precipitated thin layers were ~4-6 mkm. Since the planche is circular, thin layers are also obtained circularly, and their diameter is smaller than the diameter of the SnO₂ layer on the surface of the glass. Then a thick layer from the nickel material with omic contact was formed on the remaining surface of SnO₂ by masking method. Such nickel is also formed on the upper surface of the contact structure. In the solar element, carriers are excited by absorbing light quanta and begin to move from the valence zone to the conductivity zone. The resulting electron-hole pairs are separated from the effect of the electric field on the potential crossbar at the p-n junction and provide the basis for the photovoltaic process. In the dark and light, VAXs of solar element were drawn and it became apparent that the opposite arm of the characteristic was more sensitive to illumination. Both VAXs have linearity on the their opposite arms, but at a voltage of -30 V, there is a slight fracture in the opposite arms. From the measurements, it was found that the photocurrent short circuit (I_{sc}) of heterocyclic depended on the change in light intensity (E) as follows:

$$I_{sc} \sim E^m.$$

It has been defined that this dependence is increasing linearly and that the value of m quantification can be calculated based on the tendency of the increase. At higher lighting prices, the m coefficient gets smaller values than the unit, which limits the

boundary of the solar element's operating range. In order to clarify this issue, the dependence of the short-circuit current on the light intensity was investigated. Using the dependence $V_{oc} = \frac{1}{A \ln\left[\left(\frac{I_{nsc}}{I_{nS}}\right) + 1\right]}$, the output power of the solar element can be estimated. Here, in the $A = \frac{q}{nkT}$ formula, n quantification is considered as an idealizing factor in illumination, and its value is calculated from the dependence of $\ln I_{sc} \sim f(U_{oc})$. Using the values of I_{sc} and U_{oc} , it was determined that the VAX filling factor of solar element was $FF = 0.44$. The value of the solar element open circuit voltage was $U_{oc} = 16.8$ V, short-circuit current was $I_{sc} = 0.88$ mA and other parameters was also found. The coefficient of performance (CP) of the element was $\eta \approx 6,5\%$.

RESULTS

1. By differential thermal, microstructure, X-ray phase and property - composition analysis methods [InTe-(Cr₂Te₃, CoTe₂, TiGaTe₂, TlInSe₂, TlBiTe₂, CuGaTe₂, Bi_{1,3}Sb_{0,7}Te₃, CuCr₂Te₄, Cu₂ZnSnS₄)] vø [In₂Te₃-(MnTe₂, Ni₃Te₄, CuInSe₂, CuGaSe₂, Cd_{0,9}Zn_{0,1}Te, CuCr₂S₄, Cu₂Ga₄Te₇, Cu₂In₄Te₇, CuZn₂InTe₄)], (CuTe-Cr₂Te₃) systems were elucidated and state diagrams were constructed to show that in these systems solid solution fields with complex composition, new ternary and quaternary compounds are obtained. The boundaries of the solid solution areas were defined, their physical-chemical, thermodynamic properties were studied and the character of chemical communication in them was clarified.
2. It has been determined that in the systems with In₂Te₃ compound, phase transitions specific to this compound are observed, in which the nature of the phase transitions due to the influence of the second components becomes both eutectoid and peritectoid. Based on the electronic structures of the elements of the new InCr₂Te₄ compound, computer prediction was carried out using the method of discriminant regression functions, and the

availability of the compound was confirmed theoretically. As a result of special technological ways, nanowire-shaped crystals of $(\text{In}_2\text{Te}_3)_{1-x}(\text{Cu}_2\text{Ga}_4\text{Te}_7)_x$ alloys were obtained, and their fractal growth image was studied.

3. The weakening of the chemical bonds in some solid solutions based on In_2Te_3 was clarified based on the dependence of phonon thermal conductivity on microhardness. From the comparative analysis of the width of the solubility zones found in the systems, it was concluded that the reason for the expansion of the solubility zone in the $\text{Cr} \rightarrow \text{Mn} \rightarrow \text{Ni}$ direction in the composition of the second components added to indium tellurides is that chromium has a more stable electronic structure compared to other 3d-elements.
4. $(\text{In}_2\text{Te}_3)_{1-x}(\text{MnTe}_2, \text{Ni}_3\text{Te}_4)_x$ in solid solutions it was determined from the temperature dependences of the kinetic coefficients that the scattering of charge carriers at low temperatures is caused by ionized additive atoms, and at high temperatures mainly by thermal oscillations of the crystal lattice. Heat transport in $(\text{In}_2\text{Te}_3)_{1-x}(\text{MnTe}_2)_x$ solid solutions occurs by multi-phonon mechanisms, and at high temperatures, additional phonon thermal resistance occurs in the samples. In $(\text{In}_2\text{Te}_3)_{1-x}(\text{Ni}_3\text{Te}_4)_x$ alloys, heat transport occurs by a one-phonon mechanism and no additional lattice thermal resistance occurs. The structural change occurring in the electron-phonon scattering in the indicated alloys is also determined by the temperature dependence of the dimensionless Nernst-Ettingshausen coefficient.
5. Based on the temperature dependences of the kinetic coefficients of $(\text{In}_2\text{Te}_3)_{1-x}(\text{Cd}_{0,9}\text{Zn}_{0,1}\text{Te})_x$ solid solutions, it was determined that electron and phonon scattering mechanisms in these alloys are complex in different temperature ranges. Since the studied solid solutions are made on the basis of In_2Te_3 , which is rich in vacancy type defects, it is justified that phonon scattering in these materials also occurs from point defects. It has been established that multi-phonon thermal scattering mechanism, which is observed with the formation of additional phonon thermal resistance at high temperatures, is predominant.

6. In the InTe compound and $(\text{InTe})_{1-x}(\text{TlGaTe}_2)_x$ solid solutions were determined that of thermal-physical and galvanomagnetic parameters dependences from the temperature in both indium monotelluride and $(\text{InTe})_{1-x}(\text{TlGaTe}_2)_x$ solid solutions is low-temperature single-phonon, and at high temperatures, heat transport is related to the mechanism that occurs on electrons and excitons.
7. Based on the study of the influence of the $\text{Cu}_2\text{ZnSnS}_4$ compound on the thermoelectric properties of InTe and electron-phonon phenomena, the value of the Grüneisen coefficient was calculated ($\gamma=2,7$) and it was concluded that at high temperatures the degree of anharmonicity of phonon phenomena is high level. It has been detected that $(\text{InTe})_{0,98}(\text{Cu}_2\text{ZnSnS}_4)_{0,02}$ solid solution has high thermoelectric efficiency ($Z=1,5 \cdot 10^{-3} \text{ K}^{-1}$) at 800.K temperature. It has been determined that $(\text{Cr}_2\text{Te}_3)_{1-x}(\text{In}_2\text{Te}_3)_x$ and $(\text{CuCr}_2\text{Te}_4)_{0,99}(\text{InTe})_{0,01}$ solid solutions have a high thermoelectric efficiency ($Z_{600\text{K}}=2,0 \cdot 10^{-3} \text{ K}^{-1}$) of practical importance are materials. $(\text{CuCr}_2\text{Te}_4)_{0,99}(\text{InTe})_{0,01}$ solid solution has semimetallic conductivity ($\Delta E=0,32 \text{ eV}$) and anomalies are observed in the temperature dependence of its kinetic coefficient. The effective mass in the alloy increases with increasing temperature; ($m^*/m=0,26$ (160K) and $m^*/m = 1,17$ (700K) which is related to the fact that the solid solution has a complex zone structure. It has been found that $(\text{CuCr}_2\text{Te}_4)_{0,99}(\text{InTe})_{0,01}$ has a high thermoelectric efficiency ($Z_{700} = 2,0 \cdot 10^{-3} \text{ K}^{-1}$) and can be used in the preparation of thermogenerators operating in the medium temperature range.
8. In experimental researches, the mechanisms of electron-phonon transport in $(\text{Cu}_2\text{Ga}_4\text{Te}_7)_{1-x}(\text{In}_2\text{Te}_3)_x$ solid solutions were clarified and it has been shown that in electron scattering events, in addition to scattering from ionized additive atoms and thermal oscillations of the crystal lattice, there is also a scattering mechanism from polarized optical oscillations. Phonon scattering during heat transport in this solid solution occurs according to the "ejection" (U-processes) mechanism.
9. From the study of the temperature dependences of the kinetic coefficients of the obtained $\text{CuGa}_2\text{InTe}_5$ compound, it was found

that the transport of electric energy and heat is of a mixed nature, and at high temperatures the mechanism of bipolar heat conduction prevails the reason for the different nature of the transport mechanisms is the multicomponentity of the $\text{CuGa}_2\text{InTe}_5$ compound and the complex energy zone structure.

10. Thermal deposition technology with the "hot wall" variant were obtained n-InTe/p- n-InTe/p-TlGaTe₂ vø p-InTe/n-TlInSe₂ structures thin-film heterojunctions and their photoelectric, volt-ampere and volt-farad characteristics were studied, and it was shown that n-InTe/p-TlGaTe₂ heterojunction has high photoconductivity and can be used as a sensitive recording device at near-infrared wavelengths. It has been shown that in the p-InTe/n-TlInSe₂ heterojunction, generation-recombination processes prevail in the area of space charges, the process of transition of active centers in the contact areas of the heterojunction from recombination to scattering occurs. Based on the conversion effect of $(\text{In}_2\text{Te}_3)_{0,97}(\text{MnTe}_2)_{0,03}$ content of VAX, a thin-film electronic key was developed, its signal conversion time, conversion potential, size of clock tact, geometric dimensions of the active layer and other application parameters were calculated.
11. Thermocouple constructions for thermoelectric power converters were developed using a solid solution with high thermoelectric efficiency and new compounds, their main parameters and application possibilities were studied, simple state diagrams were studied for effective contact of the p- and n-arms of the thermocouple from binary eutectic compositions. shown to be used as switching layers.
12. The construction of the thermocouple was developed using the $(\text{Bi}_{1,3}\text{Sb}_{0,7}\text{Te}_3)_{,99}(\text{InTe})_{0,01}$ solid solution with high thermoelectric efficiency, and the scientific basis of the principles of amplifying weak signals was developed with its use. It was recommended to prepare the element used as a thermoresistor in the electric circuit designed for this purpose from $(\text{In}_2\text{Te}_3)_{0,95}(\text{Ni}_3\text{Te}_4)_{0,05}$ solid solution.

13. The construction of the active element of the Ni-SnO₂/p-(CuInSe₂)_{0,99}(In₂Te₃)_{0,01}/n-TlInSe₂/Ni structure solar cell and its equivalent electrical circuit, as well as the energy diagram, were drawn up. VAX of the active element in the light and in the dark, short-circuit current, dependence of the open circuit voltage on the illumination intensity were studied and the output power $P_0 = I_{sc} \cdot U_{oc} = 14,784 \text{ mVt}$, the filling factor of the $FF=0,44$, f.i.e $\eta \approx 6,5 \%$, was found that the short circuit current $I_{q.q.}=0.88 \text{ mA}$ and the open circuit voltage $U_{a.d.}=16.8 \text{ mV}$.

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