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Short Communication

Character of Chemıcal Interactıon in Bi_2Se_3-Tb_2Se_3 Systems

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Abstract

Chemical interaction in the Bi_2Se_3-Tb_2Se_3 system was studied using physicochemical analysis methods (differential thermal analysis, X-ray phase analysis, microstructural analysis, microhardness measurement and density determination).

Based on the analysis results, a phase diagram of the Bi_2Se_3-Tb_2Se_3 system was constructed. It was found that the Bi_2Se_3-Tb_2Se_3 section is a quasi-binary section of the Tb-Bi-Se ternary system and belongs to the eutectic type.

In the Bi_2Se_3-based system, a region of solid solution of 8mol. % Tb_2Se_3 is formed at room temperature. The area of the solid solution was determined by microstructural analysis and is 13mol. % at a eutectic temperature of 813K and 8 mol. % Tb_2Se_3 at room temperature. It is evident from the phase diagrams that in the Bi_2Se_3-Tb_2Se_3 section a new ternary incongruently melting compound of the $TbBiSe_3$ composition is formed by a peritectic reaction at a temperature of 1150K with a component ratio of 1:1.

According to the results of X-ray phase analysis, it was established that the $TbBiSe_3$ compound crystallizes in the orthorhombic syngony with the lattice parameters: a=12.25, b=12.66, c=4.76Å. The solubility of Tb_2Se_3 in Bi_2Se_3 is 5.0mol.% at 300K, respectively.

Keywords: System; Analysis; Crystallization; Phase; Diagram; Temperature

Introduction

Modern scientific and technical progress is inextricably linked with the development of semiconductor technology [1-3]. The rapid development of the latter was the main stimulus for the search for complex semiconductor materials [4-6]. However, the growing need for semiconductor technology in materials is not yet fully satisfied due to the lack of materials with different combinations of optical, magnetic and electrophysical properties.

Terbium chalcogenides of the composition Tb_2X_3(X-Se, Te) and solid solutions based on them are used as thermoelectric materials in the manufacture of n-legs of thermoelectric devices. Chalcogenides of rare earth elements and alloys based on them are promising compounds for the development of thermoelectric materials [7,8]. Therefore, obtaining new materials based on them is an urgent task [9-11].

Experimental Part

For the synthesis of samples, terbium metal ingots TbM-1 purity 99.9%, bismuth grade (B-4) and selenium (B-4) were used. The synthesis mode was selected based on the physicochemical properties of the elementary components, binary compounds. The alloys were obtained by direct fusion of the components in evacuated quartz ampoules at 1600K, followed by slow cooling with the furnace turned off.

Samples with a content of 60mol% Tb_2Se_3 and higher were obtained as a sinter. They were re-crushed and converted into tablets. Alloys with a content below 60mol% are compact, dark gray in color with a metallic luster.

To achieve homogeneity of the alloy after synthesis, it was additionally annealed at temperatures 50-100K below the solidus for 250g. The obtained samples were subjected to detailed physicochemical study. The heating and cooling curves of the alloys were recorded on a Termoksan, X-ray diffraction was performed on an X-ray diffractometer.

Differential thermal analysis alloys of the system were carried out on a TERMOSKAN-2 device with an accuracy of 3-5**°C**, a chromel-alumel thermocouple, and calcined Al_2O_3 served as the standard. Heating rate of 9 degrees/min. High-temperature differential thermal analysis was carried out on a device (HTDA) - 8m_2 in an inert atmosphere using a B-B/Re thermal suspension, degreasing speed of 5rev/min.

X-ray phase analysis was performed on an X-ray instrument of the D2 PHASER model through the use of CuK**α** radiation with a Ni filter. The micro-structural analysis of alloys was carried out using an MIM-8 microscope. In the study of alloy microstructure, an etchant of composition 1 N HNO3 + HF = 2:1 was used, the etching time was 20s. The microhardness of the phases was measured on a PMT-3 instrument with an accuracy of 5%, and the density of the samples was determined by the pycnometric method.

Results and Discussion

The amount of selenium was taken in excess to maintain the stoichiometric composition. The thermograms of the alloys show that the observed heating effects are endothermic and reversible. The results of differential thermal analysis are given in Table 1.

Table 1: Results of differential thermal analysis.

№	Composition, mol %		Thermal Heating Effects, K	Microhardness, MPa		
	Bi_2Se_3	Tb_2Se_3		Bi_2Se_3	$TbBiSe_3$	Tb_2Se_3
1	100	0	980	850	-	-
2	99	1	875,980	860	-	-
3	98	2	860,970	910	-	-
4	97	3	835,975	960	-	-
5	95	5	815,835	980	-	-
6	93	7	825,845	970	-	-
7	90	10	815,840	980	-	-
8	85	15	815,825	not measured	-	-
9	80	20	815,820	eutectic	eutectic	-
10	75	25	815,875	-	-	-
11	70	30	815,975	-	-	-
12	60	40	815,995,1100	-	not measured	-
13	55	45	815,995,1200	-	1250	-
14	50	50	995,1215	-	1250	-
15	45	55	995,1310	-	1250	-
16	40	60	995,1485	-	1240	-
17	30	70	995,1615	-	not measured	2360
18	20	80	995	-	-	-
19	10	90	995	-	-	-
20	0	100	2010	-	-	2360

Based on the results obtained by the above methods, a phase diagram of the Bi_2Se_3-Tb_2Se_3 system was constructed (Figure 1).

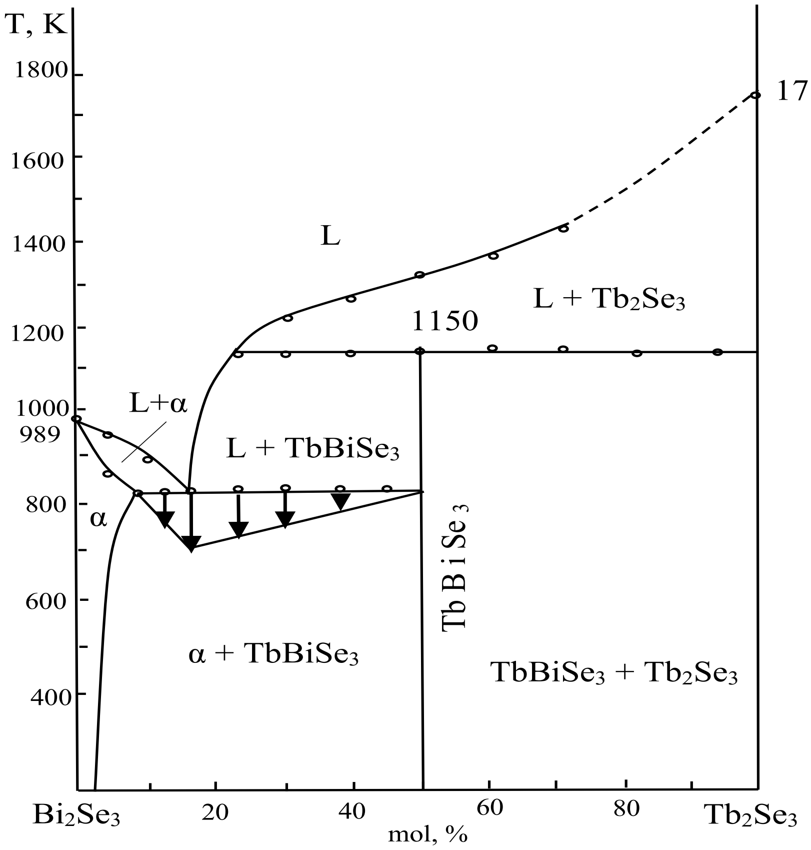

Figure 1: Phase diagram of the Bi_2Se_3-Tb_2Se_3 system.

As can be seen from the figures, the systems are quasi-binary and eutectic. From the phase diagram of the Bi_2Se_3- Tb_2Se_3 system, it is clear that at a ratio of 1:1, peritectic formation of a compound of the $TbBiSe_3$ composition occurs at a temperature of 1150K.

$$L + Tb_2Se_3 \leftrightarrow TbBiSe_3$$

A solubility region of up to 5mol.% at 300K was found. $TbBiSe_3$ forms a eutectic with Bi_2Se_3 at 85mol.%. The compound $TbBiSe_3$ with an α-solid solution based on Bi_2Se_3 forms a eutectic containing 15mol% Tb_2Se_3, which melts at 1150K. The solubility of Tb_2Se_3 in Bi_2Se_3 at 300K is 5mol%.

By indexing the X-ray diffraction patterns of $TbBiSe_3$ powders, it was established that the compound crystallizes in the orthorhombic syngony with the Sb_2S_3 type structure. The unit cell parameters are a=12.25, b=12.66, c=4.76Å.

Conclusion

1. Based on the results of physicochemical analysis, phase diagrams of the Bi_2Se_3-Tb_2Se_3 systems were constructed.
2. It was established that a ternary compound of the composition $TbBiSe_3$ is formed in the Bi_2Se_3-Tb_2Se_3 system. The $TbBiSe_3$ compound crystallizes in the orthorhombic syngony of the stibnite type: a=12.25, b=12.66, c=4.76Å.

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