Investigation of the Er$_2$Se$_3$-Bi$_2$Se$_3$ system

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Abstract. Methods of physicochemical analysis, namely differential thermal analysis (DTA), high temperature differential thermal analysis (HTTA), X-ray phase analysis (XRD), microstructural analysis (MSA) and microhardness measurements are used to determine the nature of the physicochemical interaction in the Er$_2$Se$_3$-Bi$_2$Se$_3$ ternary system. In the system based on Bi$_2$Se$_3$, solid solutions are formed, the boundaries of which are up to 3 mol% Er$_2$Se$_3$ at room temperature, and at the eutectic temperature it reaches about 8 mol% Er$_2$Se$_3$. The ternary combination of ErBi$_2$Se$_3$ with an α-solid solution forms a eutectic, the coordinates of which are 20 mol% Er$_2$Se$_3$ and 810 K.

Keywords: system, phase, crystallization, alloy, temperature, section, liquidus
**CHEMISTRY AND MATERIALS SCIENCE**

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**Introduction**

Chalcogenides of antimony and bismuth are promising materials for optoelectronic devices [1, 2], solar cells [3], thermoelectric converters [4-6], photo electrochemical cells [7], optical recording [8], lithium-ion batteries [9, 10].

According to [15, 16], one of the effective and promising ways to improve the thermoelectric properties of compounds is doping.

The study of chemical interaction in Er-B-X (B-Sb, Bi; X=S, Se, Te) systems is of interest from the point of view of improving thermoelectric properties.

**Experimental part**

The initial materials for the synthesis of alloys were Er metal "Erm-O"; Bi "B-4"; Se "B-4".

The alloys were obtained by direct alloying of the components in evacuated quartz ampoules at 900-1300K, depending on the composition, followed by slow cooling in a switched off furnace. To obtain an equilibrium state, the alloys were subjected to homogenizing annealing in evacuated quartz ampoules at temperatures 50-100 K below the solidus temperature for two weeks.

The study was carried out by a complex of methods of physical and chemical analysis.

Differential thermal analysis (DTA) was performed using an NTR-73 pyrometer and Thermoscan-2. The liquidus temperature of the high-temperature part of the diagrams was determined on a VDTA-8 in an inert atmosphere using W-W/Re thermocouples. Heating rate 40 deg./min.

X-ray diffraction analysis (XRD) was carried out by taking X-ray diffraction patterns of powders on a Bruker D8 ADVANCE diffractometer with Cu Kα radiation.

For microstructural analysis (microscope MIM-7), an etchant with the composition of 10 % mol H₂SO₄ + 45r K₂Cr₂O₇ + 90 mol% H₂O was used. Etching time was 26s.

The microhardness of the alloys was measured on a PMT-3 microhardness tester at loads of 10 and 20 g. The measurement error was 2.2–4.3%.

**Results and discussions**

After homogenization of the samples was completed, physicochemical analysis was carried out. Based on the results
of differential thermal analysis of the samples, it was established that the Er2Se3-Bi2Se3 section is a quasi-binary section of the Er-Bi-Se ternary system. The state diagram of the Er2Se3-Bi2Se3 system has been constructed (Fig.1).

![Phase diagram of the Bi2Se3-Er2Se3 system](image)

It can be seen from the figure that the Bi2Se3-Er2Se3 section belongs to the simple eutectic type. At a ratio of components of 1:1, a ternary compound of composition ErBiSe3 is formed in the system by a peritectic reaction at a temperature of 1285 K.
The ErBiSe$_3$ compound forms a eutectic with an α-solid solution based on Sb$_2$Te$_3$. Eutectic coordinates is 80 mol% Bi$_2$Se$_3$ and 800 K.

The formation of solid solutions based on Bi$_2$Se$_3$ was found, the boundary of which is approximately 3 mol.% Bi$_2$Se$_3$ at a temperature of 300 K.

By indexing the diffraction pattern of the 1:1 composition alloy, it was found that ErBiSe$_3$ crystallizes in a tetragonal syngony with unit cell parameters, $a = 18.95\text{Å}$; $c = 12.68\text{Å}$.

**Conclusion:**

By using the DTA, HTDA, XRD, MSA and microhardness measurements, the character of the physicochemical interaction in the Er-Bi-Se ternary system are studied. It has been established that the Bi$_2$Se$_3$-Er$_2$Se$_3$ sections are quasi-binary.

**References:**


