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Interaction of the Components in Ti–{Si, Ge}–Bi Systems at 670 K

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The interaction of titanium with silicon or germanium and bismuth over the whole concentration range has not yet been studied. Therefore, the binary systems of the Ti–{Si, Ge}–Bi ternary systems have been widely studied, including the phase diagrams over the whole concentration range. Before investigation of ternary equilibrium diagrams, we confirmed the existence of the binary compounds. Two intermetallic phases exist in Ti–Bi system at 670 K [1]. Ti_2Bi (Ti_2Bi structure type) [2,3] intermetallic compound has been found at 66.7 at. % of Ti. An intermetallic phase, which has been found at ~75 at. % of Ti is in equilibrium with this compound and pure titanium. Auer-Welsbach *et al*. [3] and Nowotny *et al*. [4] were the first to report the existence of this compound of the composition Ti_4Bi, based on a structural similarity to Ti_4Pb (hexagonal Ni_3Sn type of structure). According to the metallographic and X-ray investigations [5], however, this phase has the stoichiometry Ti_3Bi with a tetragonal structure. We could not determine the crystal structure of the phase, which we found, because we obtained a poor quality diffractogram. Both of these compounds (Ti_2Bi and Ti_3Bi) are characterized by constant compositions.

Five binary compounds exist in Ti–Si system at 670 K [1,6,7]. Ti_3Si (Ti_3P structure type), Ti_5Si_4 (Zr_5Si_4 type), TiSi (FeB type) and $TiSi_2$ ($TiSi_2$ type) compounds have stable compositions. Ti_5Si_3 (Mn_5Si_3 type) possesses the homogeneity range of 36.5–38.5 at. % Si.

Three binary compounds exist in Ti–Ge system at 670 K [1,6,8]. These are Ti_5Ge_3 (Mn_5Si_3 structure type), Ti_6Ge_5 (Ti_6Ge_5 type), $TiGe_2$ ($TiSi_2$ type). We could not find Ti_3Ge (Ni_3P type) and TiGe (anti-TiSi type). All these compounds are characterized by constant compositions. Crystallographic parameters for the binary phases, existing in these systems, are given in Table 1. No binary compounds exist in Si–Bi and Ge–Bi systems. The Si–Bi system is characterized by a monotectic transformation at 1673 K and an eutectic transformation close to the melting point of bismuth. The Ge–Bi system is characterized by an eutectic transformation very close to the melting point of bismuth [1].

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Table 1. Crystallographic parameters for the binary phases in Ti–{Si, Ge}–Bi systems.

Compound	Structure type	Space group	Lattice parameters, nm			Ref.
			a	*b*	*c*	
Ti_3Si	PTi_3	$P4_2/n$	1.0196	–	0.5097	6
Ti_5Si_3	Mn_5Si_3	$P6_3/mcm$	0.7461	–	0.51508	6
Ti_5Si_4	Zr_5Si_4	$P4_12_12$	0.7133	–	1.2977	6
TiSi	FeB	*Pnma*	0.657	0.364	0.503	6
$TiSi_2$	$TiSi_2$	*Fddd*	0.8236	0.4773	0.8523	6
Ti_3Ge	Ni_3P	$I\bar{4}$	1.029	–	0.514	6
Ti_5Ge_3	Mn_5Si_3	$P6_3/mcm$	0.7537	–	0.5223	6
Ti_6Ge_5	Ti_6Ge_5	*Ibam*	1.6915	0.7954	0.5233	6
TiGe	FeB	*Pnma*	0.3807	0.5230	0.6833	6
$TiGe_2$	$TiSi_2$	*Fddd*	0.8588	0.5032	0.8862	6
Ti_3Bi		*tetrag.*	0.6020	–	0.8274	4
Ti_2Bi	Ti_2Bi	*I4/mmm*	0.4050	–	1.4500	2

In this communication we present the results for the isothermal section of Ti–Si–Bi system and Ti–Ge–Bi system at 670 K. The samples were prepared by reaction of the elements. High purity metals (titanium – 99.99; silicon – 99.999; germanium – 99.999; bismuth – 99.99) were used. Alloys have been prepared by arc melting under a protective argon atmosphere (with Ti as a getter), using a nonconsumable tungsten electrode. During arc melting the weight losses were less than 1.5%. The alloys were annealed in quartz ampoules under vacuum at 670 K for 360 h.

Isothermal section of the phase diagrams of Ti–Si–Bi and Ti–Ge–Bi systems have been constructed by X-ray phase analysis. Powder patterns for the phase analysis

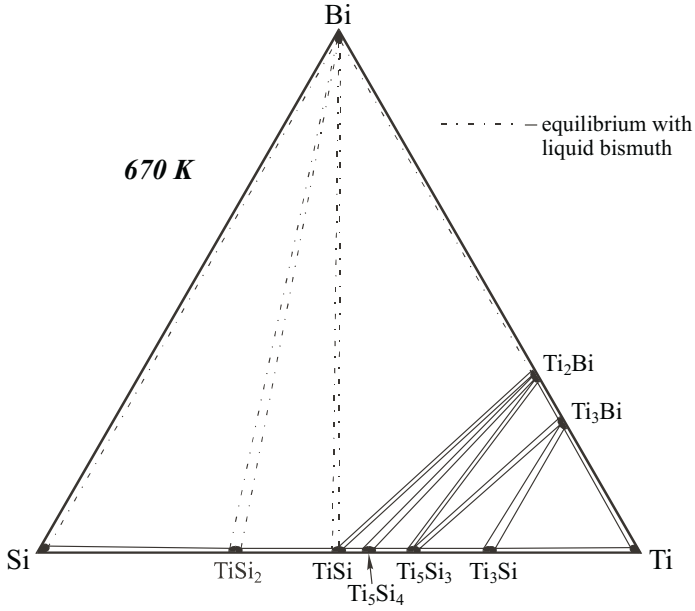

Figure 1. Isothermal section of Ti–Si–Bi system at 670 K.

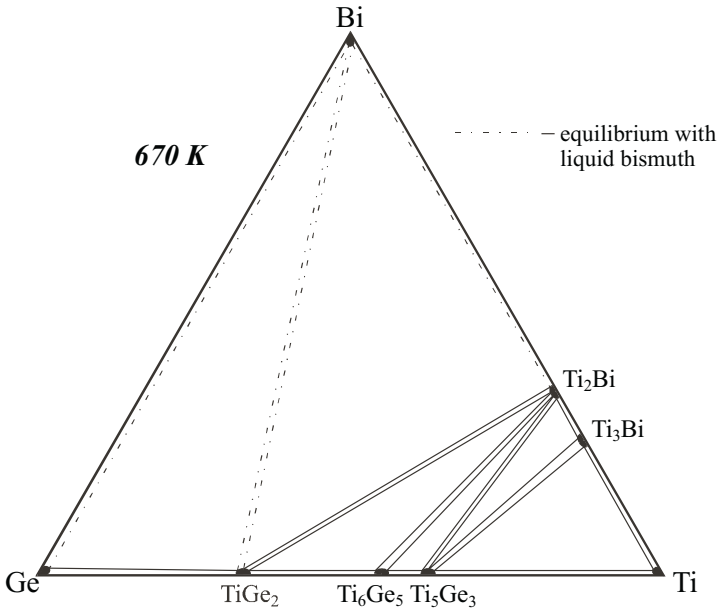

Figure 2. Isothermal section of Ti–Ge–Bi system at 670 K.

were obtained on powder diffractometers DRON-2.0 (FeK_α-radiation) and DRON-3M (CuK_α-radiation, 0.05° step of scanning, 10 sec./one point speed of scanning). Indexing of the diffractograms has been made by the program TREOR-90. The cell constants have been refined using the program LATCON.

By comparing and analysing the X-ray diffraction patterns of 72 samples and identifying the phases in each sample, the isothermal section at 670 K of the phase diagrams of the Ti–{Si, Ge}–Bi ternary systems has been determined. For the Ti–Si–Bi ternary system at 670 K it is shown in Fig. 1 and that of Ti–Ge–Bi – in Fig. 2. No ternary compounds and solid solutions on the bases of binary compounds have been found.

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