INTERACTION BETWEEN THE COMPONENTS IN Tm-Cr-Ge SYSTEM

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The phase equilibrium diagram of the Tm–Cr–Ge ternary system was constructed at a temperature 1070 K based on the results of X-ray phase, microstructural analyzes and energy-dispersive X-ray spectroscopy in the whole concentration range.

To study the interaction of thulium with chromium and germanium alloys were synthesized by a direct twofold arc-melting of the constituent elements under high purity Ti-gettered argon atmosphere on a water-cooled copper bottom. For better homogenization the samples were re-melted twice. For heat treatment, the alloys were placed in vacuum quartz ampoules and annealed at 1070 K for 700 h. X-ray phase analysis of the samples was carried out using the powder patterns obtained on DRON-4.0 (Fe$K\alpha$ radiation) diffractometer. The observed diffraction intensities were compared with reference powder patterns of binary phases, known ternary germanides and pure elements. To control the chemical composition of the synthesized samples, determine the exact content of components in the phases and confirm the results of X-ray phase analysis we used the method of energy-dispersive X-ray spectroscopy (EDRS) (electron microscope TESKAN VEGA 3 LMU). At least five measurements were taken to obtain the average value for each phase in each sample. For the crystal structure refinements the diffraction data were collected at room temperature using STOE STADI P diffractometer (graphite monochromator, Cu $K\alpha_1$ radiation). FullProf Suite software package was used for crystal structure calculation.

Isothermal section of the Tm-Cr-Ge ternary system is illustrated in Fig. 1. Microphotographs of some alloys are presented in Fig. 2.

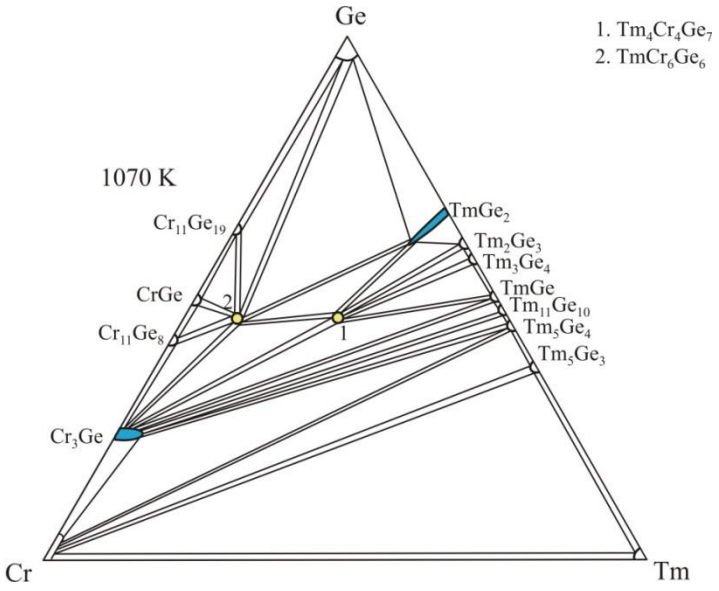

Fig. 1 Isothermal section of the Tm–Cr–Ge system at 1070 K

According to the results of X-ray phase and EPM analyzes at a temperature of 1070 K in the Tm–Cr–Ge system the formation of two new ternary germanides $TmCr_6Ge_6$ and $Tm_4Cr_4Ge_7$ was established. Crystallographic characteristics of the ternary compounds are given in Table.

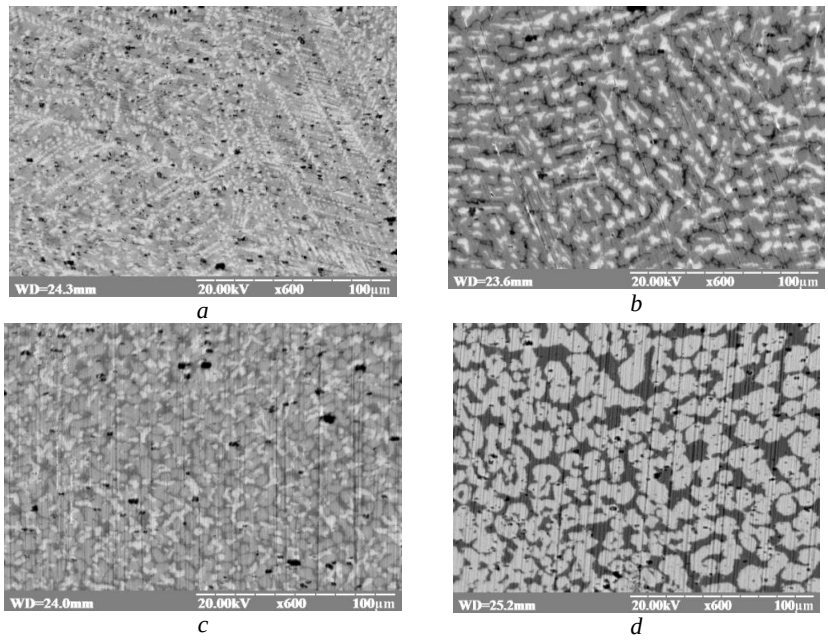

Fig. 2. Electron microphotographs of the Tm−Cr−Ge alloys:$Tm_{20}Cr_{25}Ge_{55}$ (a), $Tm_{10}Cr_{55}Ge_{35}$ (b), $Tm_{45}Cr_{10}Ge_{45}$ (c), $Tm_{20}Cr_{40}Ge_{40}$ (*d*)

Table

Crystallographic characteristics of the ternary compounds in the Tm–Cr–Ge system

N	Compound	Structure type	Space group	Lattice parameters, nm		
				a	***b***	***c***
1	$Tm_4Cr_4Ge_7$	$Zr_4Co_4Ge_7$	*I*4/*mmm*	1.39005(9)	–	0.54441(1)
2	$TmCr_6Ge_6$	$SmMn_6Sn_6$	*P*6/*mmm*	0.51506(1)	–	0.82645(2)

On the basis of the binary germanide $TmGe_2$ ($ZrSi_2$-type) the formation of an insertion-type solid solution $TmCr_xGe_2$ up to Cr content ~10 at. % was established. The limit composition of the solid solution was determined by analysis of the lattice parameters (a = 0.4004 (2) -0.4095 (7) nm, b = 1.5708 (6) -1.5601 (1) nm, c = 0.3907 (1) -0.3983 (5) nm) and electron probe microanalysis ($Tm_{29.96}Cr_{10.19}Ge_{59.85}$). Binary germanide Cr_3Ge (Cr_3Si structure type) dissolves up to ~4 at. % Tm, which is confirmed by the results of EPM analysis and changes of the lattice parameter: a = 0.4624(1) nm for Cr_3Ge, a = 0.4632(2) nm for sample $Tm_4Cr_{71}Ge_{25}$.