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Letter

Dy–Sb–Si system at 1100 K and ternary intermetallic phases in the Dy–Sb–Si and Gd–Sb–Si systems

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Abstract

Physicochemical analysis techniques, including X-ray phase analysis and electron probe X-ray analysis were employed in constructing the isothermal section of the Dy–Sb–Si system at 1100 K. The ternary intermetallic phases $Dy_{55}Sb_{16}Si_{28}$ [a=0.7746(3) nm, b=1.4853(5) nm, c=0.7761(3) nm], $Dy_{55}Sb_{31}Si_{13}$ [a=0.7802(3) nm, 1.4972(4) nm, c=0.7817(2) nm] and $Gd_{55}Sb_{15}Si_{29}$ [a=0.7892(5) nm, b=1.5128(7) nm, c=0.7925(5) nm] crystallize in the orthorhombic Sm_5Ge_4-type structure (space group *Pnma*; no. 62). $Gd_{62}Sb_{20}Si_{18}$ [a=0.8759(2) nm, c=0.6363(1) nm] crystallizes in the hexagonal Mn_5Si_3-type structure (space group $P6_3/mcm$; no. 193).

Keywords: Rare earth compounds; Crystal structure; Phase diagram; X-ray diffraction

The interaction between the components in the Sb–Si, Dy–Sb and Dy–Si binary system has been studied in detail in Refs. [1–3] (Table 1).

The present study was carried out on about 12 alloys (Fig. 1). The alloys were made in an electric arc furnace under an argon atmosphere using a nonconsumable tungsten electrode and a water-cooled copper tray. Silicon, antimony, gadolinium and dysprosium (purity of each component ≥99.99%) were used as starting components. Titanium was used as a getter during the melting process. The alloys were remelted twice in order to achieve complete fusion and homogeneous composition. The melted alloys were subjected to an anneal in evacuated quartz ampoules containing titanium chips as a getter. The ampoules were placed in a resistance furnace. The alloys were annealed at 1100 K for 2 weeks. The samples were quenched from 1100 K in ice-cold water.

The phase equilibria in the Dy–Sb–Si system were determined using X-ray phase analysis and electron probe X-ray analysis. X-ray data were obtained on a Dron-3.0 diffractometer (CuKα radiation, 2θ=20–70°, step 0.05°, for 5 s per step). The diffractograms obtained were

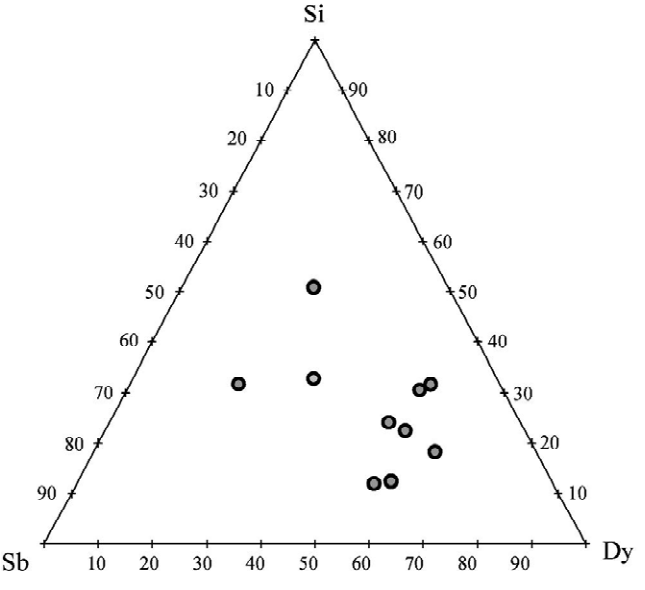

Fig. 1. Composition of samples investigated in the Dy–Sb–Si system.

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Table 1
Crystallographic data of compounds in the binary Dy–Si and Dy–Sb systems. The *R* factors are given in percent ($R_F = 100 \cdot (\Sigma_k|(I_k^{obs})^{1/2} - (I_k^{cal})^{1/2}|)/\Sigma_k|(I_k^{obs})^{1/2}|$)%, I_k^{obs} is the integrated intensity evaluated from summation of contribution of the *k*th peaks to net observed intensity, I_k^{cal} is the integrated intensity calculated from refined structural parameters

N	Compound	Space group	Structure type	*a* (nm)	*b* (nm)	*c* (nm)	R_F (%)	Refs.
1	Si[a]	*Fd*3*m*	C	0.54307				[1]
	Si[a]	*Fd*3*m*	C	0.5426(2)			3.8	[b]
2	Sb (LT)	*R*3*m*	As	0.43084		1.1247		[1]
	Sb (HT)	$P6_3/mmc$	Mg	0.3369		0.533		[1]
3	Dy (LT1)	*Cmcm*		0.3595	0.6183	0.5677		[1]
	Dy (LT2)[a]	$P6_3/mmc$	Mg	0.35903		0.56475		[1]
	Dy (HT)	*Im*3*m*	W	0.398				[1]
4	Dy_5Si_3[a]	$P6_3/mcm$	Mn_5Si_3	0.837		0.626		[1]
	Dy_5Si_3[a]	$P6_3/mcm$	Mn_5Si_3	0.856(1)		0.6046(7)	3.7	[b]
5	Dy_5Si_4[a]	*Pnma*	Sm_5Ge_4	0.736	1.448	0.765		[1]
6	DySi (HT)[a]	*Pnma*	FeB	0.787	0.380	0.565		[1]
	DySi (HT)[a]	*Pnma*	FeB	0.7866(5)	0.3816(2)	0.5655(5)	3.9	[b]
	DySi (LT)	*Cmcm*	CrB	0.4237	1.0494	0.3818		[1]
7	$DySi_{1.67}$[a]	*P*6/*mmm*	AlB_2	0.383		0.411		[1]
	$DySi_{1.67}$[a]	*P*6/*mmm*	AlB_2	0.384(1)		0.415(1)	3.5	[b]
8	$DySi_2$ (HT)	$I4_1/amd$	$ThSi_2$	0.403		1.338		[1]
	$DySi_2$ (LT)[a]	*Imma*	$GdSi_2$	0.404	0.394	1.334		[1]
	$DySi_2$ (LT)[a]	*Imma*	$GdSi_2$	0.4033(1)	0.3933(1)	1.3312(4)	3.4	[b]
9	DySb[a]	*Fm*3*m*	NaCl	0.61316				[1]
	DySb[a]	*Fm*3*m*	NaCl	0.6142(4)			5.0	[b]
10	Dy_4Sb_3	*I*43*d*	Th_3P_4	0.9114				[1]
11	Dy_5Sb_3[a]	$P6_3/mcm$	Mn_5Si_3	0.887		0.6266		[1]
	Dy_5Sb_3[a]	$P6_3/mcm$	Mn_5Si_3	0.8886(9)		0.6143(5)	3.8	[b]

[a] Compounds belong to the isothermal cross-section at 1100 K.
[b] Data for compounds from X-ray phase analysis of the three-component samples.

identified by means of calculated patterns using the RIETAN program [4,5] in the isotropic approximation. A Camebax microanalyser was employed to perform local X-ray spectral analyses of the samples.

The results obtained were used in the construction of the isothermal section of the Dy–Sb–Si system at 1100 K, presented in Fig. 2.

The ternary intermetallic phases Sm_5Ge_4-type $Dy_{55}Sb_{16}Si_{28}$, $Dy_{55}Sb_{31}Si_{13}$ and $Gd_{55}Sb_{15}Si_{29}$ were found in the Dy–Sb–Si and Gd–Sb–Si systems at 1100 K (Table 2).

It is obvious that the $Dy_{55}Sb_{16}Si_{28}$ and $Gd_{55}Sb_{15}Si_{29}$ compounds belong to extended regions of solid solutions of the Sm_5Ge_4-type Dy_5Si_4 and Gd_5Si_4 compounds. The Sm_5Ge_4-type $Dy_{55}Sb_{31}Si_{13}$ compound is a ternary compound. We have detected a Mn_5Si_3-type $Gd_{62}Sb_{20}Si_{18}$ solid solution in the Gd–Sb–Si system. Dy_5Si_3 and the other binary compounds of the Dy–Sb–Si system do not show any visible solubility.

No Th_3P_4-type Dy_4Sb_3 compound was detected in the Dy–Sb–Si system at 1100 K.

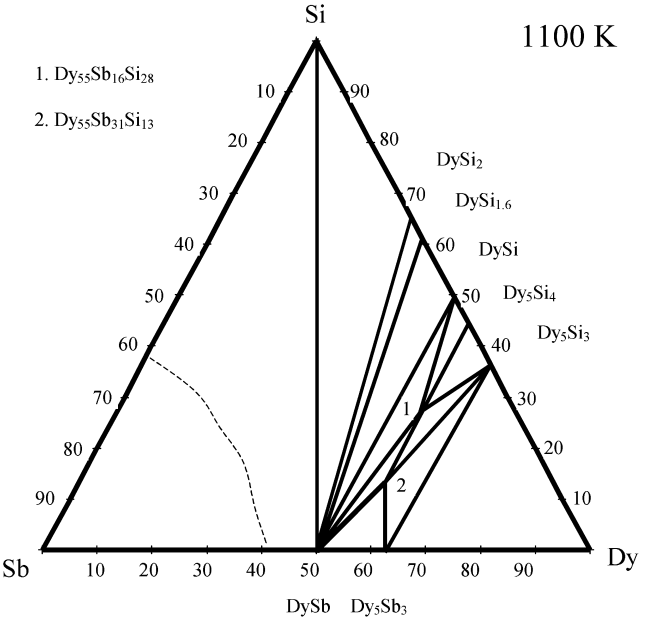

Fig. 2. Isothermal section of the Dy–Sb–Si system at 1100 K.

Table 2
Crystallographic data of ternary phases in the Dy–Sb–Si and Gd–Sb–Si systems. The R factors are given in percent ($R_F = 100 \cdot (\Sigma_k|(I_k^{obs})^{1/2} - (I_k^{cal})^{1/2}|)/\Sigma_k|(I_k^{obs})^{1/2}|$)%, I_k^{obs} is the integrated intensity evaluated from summation of contribution of the kth peaks to net observed intensity, I_k^{cal} is the integrated intensity calculated from refined structural parameters

N	Compound	Space group	Structure type	a (nm)	b (nm)	c (nm)	R_F (%)
1	$Dy_{55}Sb_{16}Si_{28}$	*Pnma*	Sm_5Ge_4	0.7746(3)	1.4853(5)	0.7761(3)	3.9
2	$Dy_{55}Sb_{31}Si_{13}$	*Pnma*	Sm_5Ge_4	0.7802(3)	1.4972(4)	0.7817(2)	3.9
3	$Gd_{55}Sb_{15}Si_{29}$	*Pnma*	Sm_5Ge_4	0.7892(5)	1.5128(7)	0.7925(5)	2.4
4	$Gd_{62}Sb_{20}Si_{18}$	$P6_3/mcm$	Mn_5Si_3	0.8759(2)		0.6363(1)	3.1

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