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Journal of Alloys and Compounds 450 (2008) 252–254

Journal of ALLOYS AND COMPOUNDS

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Phase relations in the Al–Pr–Sb system at 773 K

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Received 9 August 2006; received in revised form 26 October 2006; accepted 28 October 2006

Available online 21 December 2006

Abstract

The isothermal section of the phase diagram of the Al–Pr–Sb ternary system at 773 K over the whole concentration region has been investigated mainly by powder X-ray diffraction (XRD) with the aid of scanning electron microscopy (SEM). A new ternary compound $\sim Al_{11}Pr_{24}Sb_{65}$ has been found.

Keywords: Rare earth alloys; Phase diagram; X-ray diffraction

1. Introduction

The phase equilibria in the Ln–Al–Sb (Ln = rare earth element) ternary systems have not yet been studied sufficiently. Only the Y–Al–Sb system was reported [1,2]. The goals of this work are the construction of the isothermal section of the Pr–Al–Sb system at 773 K over the whole concentration region.

The binary systems Al–Sb, Al–Pr and Pr–Sb bounding the Al–Pr–Sb system have been investigated in detail in the literature [3]. No ternary compounds were reported in this system.

2. Experimental details

For sample preparation, the ingots of aluminum (99.9 wt.%), praseodymium (99.8 wt.%) and antimony (99.9 wt.%) were used. Samples containing less than 50 at.% Sb were prepared by arc melting in a water-cooled copper crucible with a non-consumable tungsten electrode under high pure argon atmosphere. Samples containing more than 50 at.% Sb were prepared by induction melting in a sintered Al_2O_3 crucible under high purity argon. An extra amount of antimony (3–8 wt.%) was added to compensate the loss. All alloy samples after melting were subjected to a homogenizing anneal in evacuated quartz. The samples with more than 50 at.% Sb were annealed at 870 K for 25 days, and the samples with less than 50 at.% Sb were annealed at 1000 K for 25 days. Subsequently, they were cooled to 773 K at a rate of 10 K/h and kept at this temperature for 10 days, then quenched in liquid nitrogen.

X-ray powder diffraction and scanning electron microscopy with energy dispersive analysis were used in the present investigation. Samples for X-ray diffraction analyses were powdered. The X-ray powder diffraction measurements were performed on a Rigaku D/max 2500 V diffractometer with Cu Kα radiation and graphite monochromator operated at 40 kV, 200 mA. The Materials Data Inc. software Jade 5.0 [4] and Powder Diffraction File (PDF release 2002) were used for phase identification.

3. Results and discussion

The existence of all known binary compounds in the Al–Pr system ($Al_{11}Pr_3$, Al_3Pr, Al_2Pr, AlPr, $AlPr_2$, $AlPr_3$) and the Al–Sb system (AlSb) was confirmed. In the Pr–Sb system at 773 K we have obtained five compounds Pr_2Sb, Pr_5Sb_3, Pr_4Sb_3, PrSb and $PrSb_2$. This agrees with the results presented in [5]. The mutual solid solubilities of Al in Pr–Sb and Sb in Pr–Al compounds are negligible. We have not observed the binary compound Pr_5Sb1_2 which crystallizes in monoclinic with $a = 28.591$ Å, $b = 4.263$ Å, $c = 13.561$ Å and $\beta = 95.52°$ [6]. Figs. 1 and 2 are the X-ray phase analysis results of the sample (40 at.% Pr, 60 at.% Sb) and the sample (20 at.% Pr, 80 at.% Sb), respectively. From Figs. 1 and 2, it is clear that there is $PrSb_2$ at 773 K. We also calculated the X-ray pattern of Pr_5Sb_{12}, but it did not match the observed one. It may require a higher temperature for Pr_5Sb_{12} formation. In this work, X-ray powder diffraction analysis has indicated that there is a new ternary compound. Scanning electron microscopy with energy-dispersive reveals that the composition of the new phase is about $Al_{11}Pr_{24}Sb_{65}$.

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doi:10.1016/j.jallcom.2006.10.124

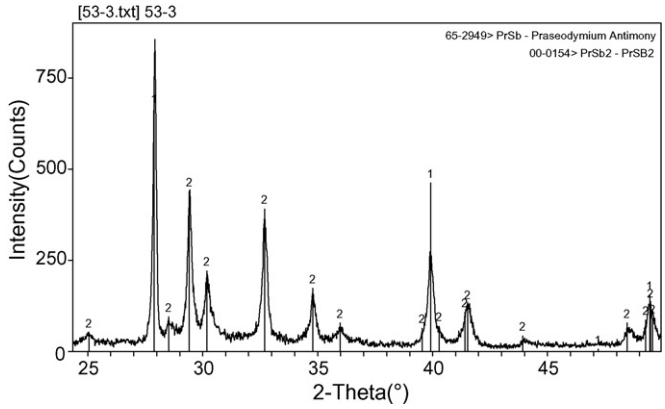

Fig. 1. Sample (40 at.% Pr, 60 at.% Sb) consists of PrSb (No. 1) + $PrSb_2$ (No. 2) two phases.

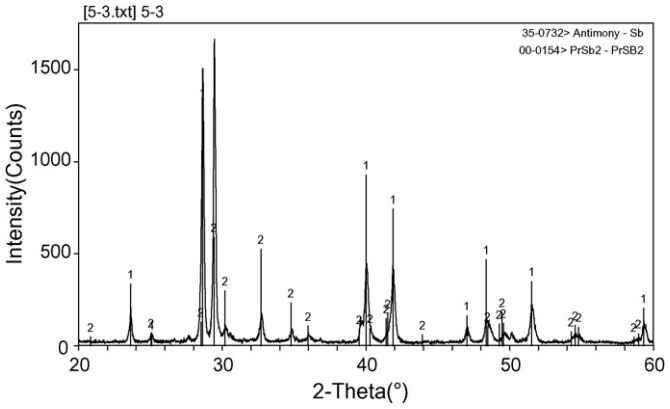

Fig. 2. Sample (20 at.% Pr, 80 at.% Sb) consists of Sb (No. 1) + $PrSb_2$ (No. 2) two phases.

Its X-ray powder diffraction patterns are shown in Fig. 3. We do not observe the homogeneity region of the new compound $Al_{11}Pr_{24}Sb_{65}$. The unknown crystal structure needs additional study.

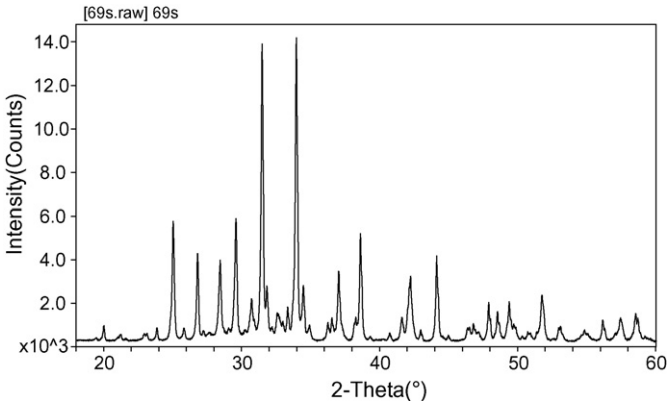

Fig. 3. X-ray powder diffraction patterns of ~$Al_{11}Pr_{24}Sb_{65}$.

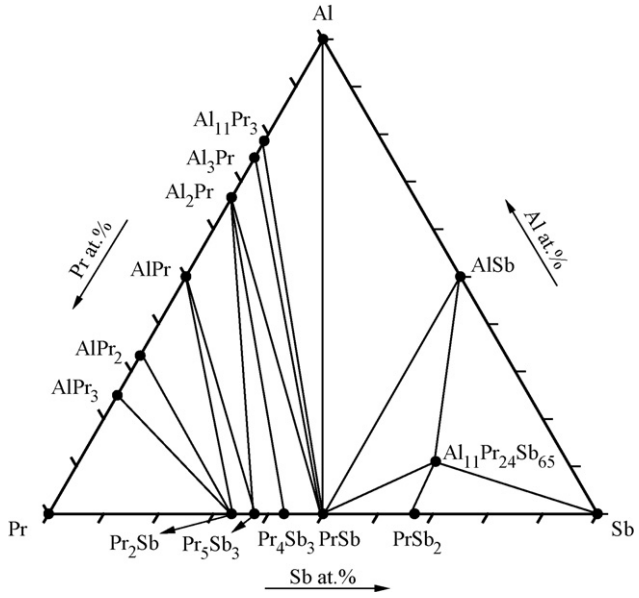

Fig. 4. The isothermal section of the Al–Pr–Sb system at 773 k.

Table 1
Crystallographic data of the initial components and compounds for the Al–Pr–Sb system

Phase	Space group	Structure type	Lattice parameter (Å)			Reference
			a	*b*	*c*	
Al	$fm\bar{3}m$	Cu	4.050(2)			[3]
Pr	$P6_3/mmc$	La	3.6715		11.83	[3]
Sb	$R\bar{3}m$	As	4.3084		11.274	[3]
$Al_{11}Pr_3$	*Immm*	$Al_{11}La_3$	4.376(2)	12.966(5)	10.023(3)	This work
Al_3Pr	$P6_3/mmc$	Ni_3Sn	6.5138(2)		4.6044 (4)	This work
Al_2Pr	$Fd\bar{3}m$	Cu_2Mg	8.0238(5)			This work
AlPr	*Cmcm*	AlEr	9.238(5)	7.652(3)	5.681(2)	This work
$AlPr_2$	*Pnma*	Co_2Si	6.770(4)	5.259(1)	9.659(2)	This work
$AlPr_3$	$P6_3/mcm$	Ni_3Sn	7.039(1)		5.454(1)	This work
AlSb	$F\bar{4}3m$	SZn	6.135			[7]
Pr_2Sb	$I\bar{4}/mmm$	La_2Sb	4.534(1)		17.739(2)	This work
Pr_5Sb_3	$P6_3/mcm$	Mn_5Si_3	9.282(2)		6.471(1)	This work
Pr_4Sb_3	$I\bar{4}3d$	P_4Th_3	9.469(2)			This work
PrSb	$Fm\bar{3}m$	NaCl	6.375			[3]
$PrSb_2$	*Cmca*	Sb_2Sm	6.224(2)	6.127(1)	18.144(3)	This work
~$Al_{11}Pr_{24}Sb_{65}$	Unknown structure					
Pr_5Sb_{12}	Cm (not observed)	Pr_5Sb_{12}	28.591(4)	4.263(1)	13.561(2)	$\beta = 95.52(1)$ [6]

The isothermal section of the phase diagram of the Al–Pr–Sb system at 773 K has been constructed by using the analysis results of 98 ternary and binary alloys. The results are shown in Fig. 4.The crystallographic data of the initial components, binary and ternary compounds of the Al–Pr–Sb system at 773 K are given in Table 1.

Acknowledgement

This work was supported by the Natural Science Foundation of Guangxi (Grant No. 0448021).

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