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The isothermal section of the Cr–Pb–Sb ternary system at 500 K

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Abstract

The phase relation of the Cr–Pb–Sb ternary system at 500 K has been investigated mainly by means of X-ray powder diffraction with the aid of optical microscopy. This section consists of five single-phase regions, seven two-phase regions and three three-phase regions. No ternary compound was found. The maximum solid solubility of Sb in Pb at 500 K was about 3.3%.

Keywords: Chromium lead antimony; Phase relation; X-ray diffraction

1. Introduction

The antimony–lead-based alloys have been studied for a long time, due to their important role in industrial applications for use as die casting alloys and in manufacturing acidic accumulators [1]. The thermodynamic properties of the Fe–Pb–Sb ternary system at 1473 K have been reported [2]. Recently, our group has begun studying the interactions between the components in (T)–Pb–Sb systems. Sun and Zeng have established the solid state phase equilibria in the Fe–Pb–Sb system at 500 K [3]. The phase interaction in the Cr–Pb–Sb system has not been reported in literature.

The binary diagrams of the Cr–Sb, Cr–Pb and Pb–Sb systems bounding the Cr–Pb–Sb are presented in [4]. At 500 K, there are two intermediate phases CrSb and $CrSb_2$ in the Cr–Sb binary system. The CrSb compound crystallizes in hexagonal with NiAs structure type [5]. Onodera et al. [6] reported its structural and electrical properties under pressure. The $CrSb_2$ is orthorhombic with FeS_2 structure type [7]. The ferromagnetic polymorph of $CrSb_2$ was reported by Takizawa et al. [8]. The Pb–Sb system was reported as a simple eutectic system. There is no binary phase in Pb–Sb system as well as in the Cr–Pb system. No ternary compounds were reported.

2. Experiment

For sample reparation, the purity of Cr, Pb and Sb used in this work is 99.5%, 99.9% and 99.95%, respectively. Most of samples, having masses of 3 g, were prepared by induction melting in a sintered Al_2O_3 crucible under high pure argon atmosphere. The Cr-rich alloys were melted in an arc furnace with a nonconsumable tungsten electrode under high pure argon. As Sb is easy to volatilize, an extra amount of Sb (about 2 wt.%) was added to compensate for the weight loss. During melting, we used an electric current as low as possible to minimize the loss of antimony by vaporizing. After melting, all alloys were subjected to a homogeneous annealing in evacuated quartz tube. The samples in the Cr-rich region were annealed at 1173 K for 360 h, the samples near the Pb–Sb region were annealed at 500 K for 960 h and other samples annealed at 673 K for 800 h. Subsequently, they were cooled at a rate of 10 K/h to 500 K and kept there for 240 h, then quenched into liquid nitrogen.

X-ray powder diffraction and optical microscope were used to analyze the samples. The samples were broken into two parts, one part for X-ray powder diffraction and the other

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for metallographic investigation. The samples for powder XRD were ground to powder not coarser than 40 μm, and annealed in an evacuated tube for 5 days at 500 K to remove the lattice strains produced by the grinding. The X-ray powder diffraction was performed on a Rigaku D/max 2500 V diffractometer with Cu Kα radiation and graphite monochromator operated at 40 kV and 250 mA. The Materials Data Inc. Software Jade 5.0 [9] and the Powder Diffraction File [10] were used for the phase analysis. The samples used for optical microscopic analysis were etched by 3% HNO_3–C_2H_5OH solution. The metallographic analysis was carried out on German Leica DMRE metallographic microscope. The magnification was set as 200×.

3. Results and discussion

3.1. Binary systems at 500 K

In this work, we have studied the binary systems Cr–Sb, Cr–Pb and Pb–Sb at 500 K to identify binary compounds before the ternary phase analysis. In the Cr–Sb system, two binary compounds CrSb [5] and $CrSb_2$ [7] are confirmed. We did not observe any solid solubility of Sb in α-Cr.

In the Cr–Pb binary system, neither Cr in Pb nor Pb in Cr shows solubility at 500 K. This result is in good agreement with that reported in [4].

In the Pb–Sb binary system, no binary compounds were found. In order to determine the maximum solid solubility of Sb in Pb, seven powder samples of $Pb_{100-x}Sb_x$ (x = 1–7) were prepared. In order to determine the lattice parameters

Table 1
The variation of lattice parameter of $Pb_{100-x}Sb_x$

Samples	Lattice parameter, a (Å)
$Pb_{99}Sb$	4.9499(1)
$Pb_{98}Sb_2$	4.9490(3)
$Pb_{97}Sb_3$	4.9484(3)
$Pb_{96}Sb_4$	4.9482(2)
$Pb_{95}Sb_5$	4.9481(2)
$Pb_{94}Sb_6$	4.9483(2)
$Pb_{93}Sb_7$	4.9482(2)

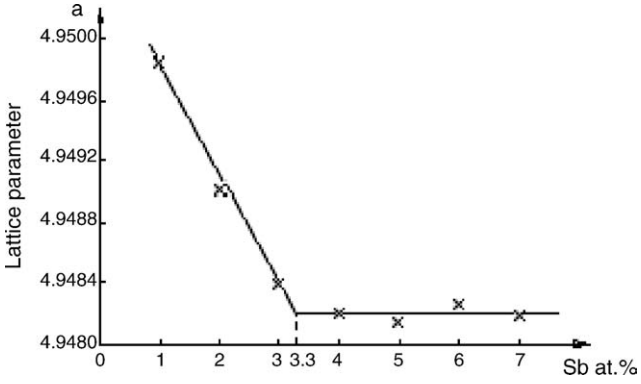

Fig. 1. Determination of the maximum solid solubility of Sb in Pb.

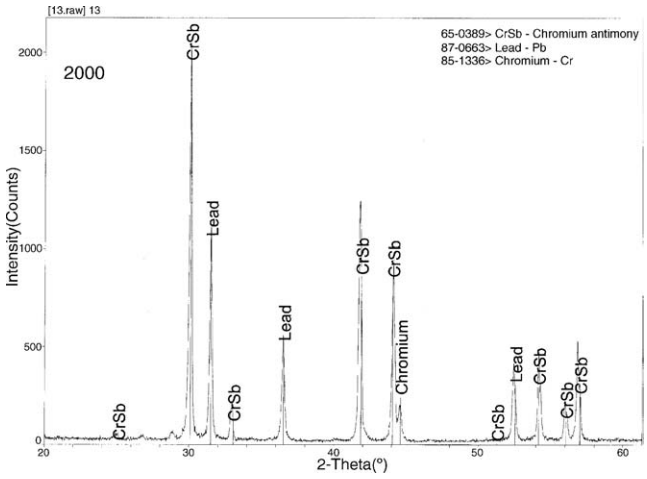

Fig. 2. The XRD pattern of alloy 1 (50 at.% Cr, 20 at.% Pb and 30 at.% Sb) consists of CrSb + Cr + Pb three phases.

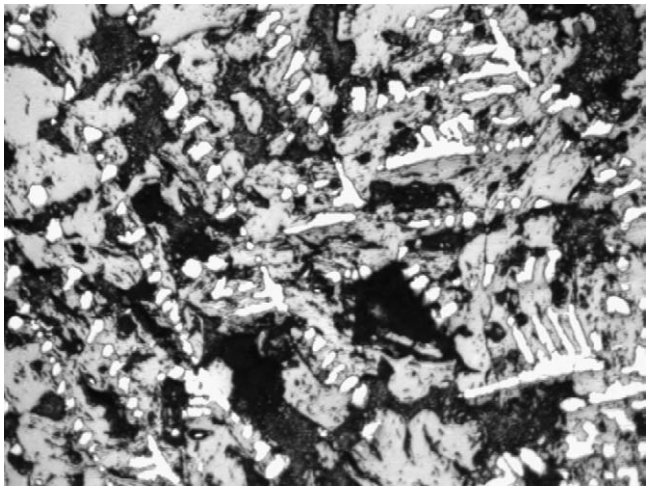

Fig. 3. Alloy 1 (50 at.% Cr, 20 at.% Pb and 30 at.% Sb) consists of CrSb + Cr + Pb three phases.

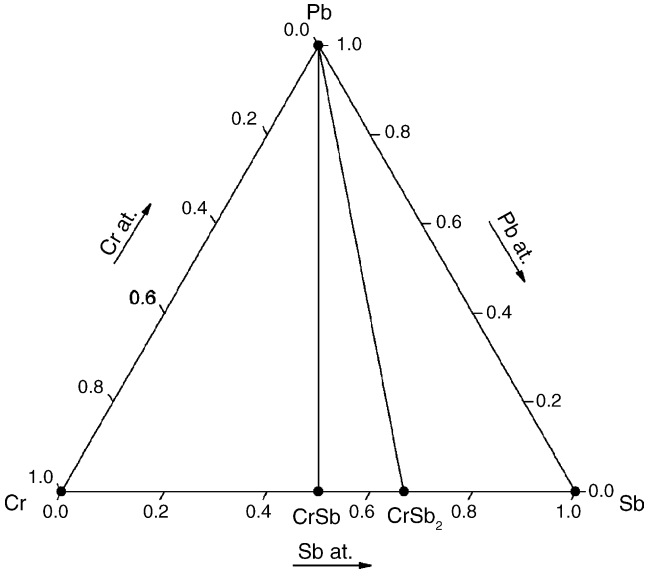

Fig. 4. The isothermal section of Cr–Pb–Sb system at 500 K.