The Terbium-Bismuth Alloy System

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The phase diagrams of Tb-Bi has been obtained. A peritec reaction develops as a result of bismuth addition, the transformation temperature of terbium being lowered by 18 °C. Eutec reactions occur at 17 at.%Bi and 1090 °C, and at more than 99 at.%Bi and 269 °C. There are four compounds in the system: Tb_5Bi_3, Tb_4Bi_3, TbBi, and $TbBi_2$, resulting from peritectic reactions at 1480, 1570, 1770 and 720 °C. While TbBi melts congruently at 1920 °C. Tb_5Bi_3 and TbBi were observed to exhibit transformation.

Key words: Terbium; Bismuth; Phase Diagram; Alloy.

1. Introduction

The purpose of this work was to study phase relationships in the Tb-Bi system and to produce a phase diagram.

Four phases between terbium and bismuth have previously been reported: Tb_5Bi_3 with the Mn_5Si_3 structure [1], $Tb_{5+x}Bi_3$ with the Y_5Bi_3 structure [2], Tb_4Bi_3 with the anti-Th_3P_4 structure [3, 4] and TbBi with NaCl structure [5].

2. Experimental

A) Materials

Terbium distillate TbMD-2 and bismuth of semiconducting purity SCH-0000 were used for the investigation. The major impurities in the terbium are given in Table 1.

Table 1. The impurity concentrations in Terbium Tb MD-2.

Impurity concentration	C	Ca	Dy, Y, Gd	Cu	Fe	Si	H_2
at %	0.003	0.004	<0.05	<0.01	<0.001	<0.01	0.002

B) Preparation of Alloys

25 compositions in the concentration range 0–50 at.%Bi and 15 compositions in the range 50–100 at.%Bi were prepared for the investigation. Each composition was prepared in duplicate or triplicate, and differential thermal analyses (DTA) of the samples were carried out in parallel. The alloys were formed from stoichiometric amounts of the powdered components placed in evacuated quartz tubes which were heated in a resistance furnace. The temperature increase of step-by-step to reach 400 °C in 70 h. Homogeneity was obtained by heating the pellets in a crucible with a lid up to a temperature will above the liquidus in an atmosphere of very pure helium. The same technique was used for both the homogeneous annealing and the thermal analysis.

C) Examination of Alloys

1. A high temperature differential thermal analyzer was used for the DTA measurements, which were made in very pure helium. The heating and cooling rates were both 30 °C/min.
2. X-ray analysis was carried out with Cu Kα radiation using a Dron-3 diffractometer.
3. A microscope of "Neofot" 32-type was used for microstructure studies.

3. Results and Discussion

An inverse peritectic reaction occurs at the terbium-rich end of the system at 1272 °C and at approximately 1 at.%Bi. Evidence for this reaction was obtained from the heating and cooling curves which showed a decrease of approximately 18 °C in the αTb ↔ βTb transformation. This decrease was caused by bismuth additions. A eutectic event occurs on the DTA curve of the sample with a content of 1 at.%Bi. Only two phases were detected by the microscopy and X-ray analyses in the range 0–37.5 at.%Bi, i.e. αTb and Tb_5Bi_3.

The temperature of the polymorphic transformation in terbium decreased by 18 °C on bismuth additions. The eutectic e_1 corresponds to 17 at.%Bi at 1090 °C. Tb_5Bi_3, being the most terbium-rich phase in the Tb-Bi system, melts incongruently at 1470 °C, but is in the DTA curves of the alloys preceded by sharp events at 1400 °C. Apparently Tb_5Bi_3 has a polymorphic transformation. Perhaps, Yoshihara et al. took for Tb_{5+X} instead

Table 2. Crystallographic data of the compounds of the alloy system.

Compounds	Crystal system	Structure type	Parameters, nm *a*	*b*	*c*	Ref.
β-Tb_5Bi_3	Orthorm	Y_5Bi_3	0.8199	0.9975	1.1999	[2]
? ($Tb_{5+x}Bi_3$)			0.819	0.948	1.187	our
α-Tb_5Bi_3	Hexagon.	Mn_5Si_3	0.91006	–	0.6365	[2]
?			0.901	–	0.639	our
Tb_4Bi_3	Cubic	anti-Th_3P_4	0.9328	–	–	[1]
			0.9325			[2]
			0.930			our
TbBi	Cubic	NaCl	0.6277	–	–	[5]
			0.628			our

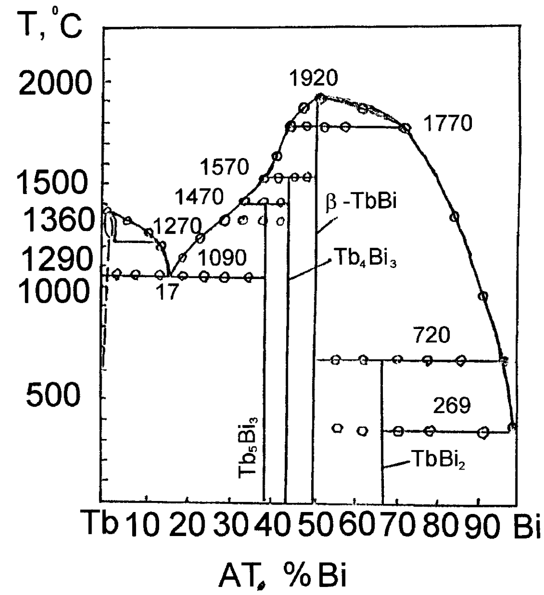

Fig. 1. Phase diagram of Tb-Bi.

β-Tb_5Bi_3 [2]. We didn't obtain one-phase samples. X-ray analysis has shown two phases. The lattice parameters of two phases of Tb_5Bi_3, have been calculated from several lines and have been coordinated with the data of other authors (Table 2). We have met the problem of polymorphic transformations in Ln_5Sb_3 in several phase diagrams of heavy REE's.

Tb_4Bi_3 forms peritecticabaly at 1570 °C. Tb-Bi melts congruently at 1920 °C and is the biggest melting phase in the system. In DTA curves, Tb-Bi shows a sharp event at 1770 °C. DTA and X-ray analyses showed a polymorphic transformation for the first time. However, Hulliger [6] has shown that monoantimonides have a high temperature modification of the CsCl-type.

The DTA curves for alloys containing 52.5–95 at.%Bi exhibit events at 720 °C as well as eutectic events. The apex of the Tamman triangle corresponds to $TbBi_2$., which was identified on the basis of DTA and metallographic data without separation into an individual phase. When alloys contacting more than 55.5 at%Bi were heated and cooled, the DTA curves showed peaks near 720 °C. At this temperature $TbBi_2$ is peritectically formed. The structure of $TbBi_2$ is unknown.

The lattice parameters of the compounds are given in Table 2, and the phase diagram of the Tb-Bi system is shown in Figure 1.

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