Determination of isothermal section of Ni-Pt-Ta ternary system at 1 173 K [①]

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[Abstract] The isothermal section of the Ni-Pt-Ta ternary system at 1 173 K was determined by means of the diffusion triple technology and the electron microprobe analysis. The phase relations in this system were studied. Linear compound (Ni, Pt) $_3$Ta with small solubility forming between Ni$_3$Ta and Pt$_3$Ta was identified. Four binary compounds, i. e. Pt$_2$Ta, Ni$_2$Ta, NiTa and NiTa$_2$, and four three-phase fields, i. e. Pt$_2$Ta+ (Ta) + NiTa$_2$, Pt$_2$Ta+ NiTa$_2$+ NiTa, Pt$_2$Ta+ (Ni, PT) $_3$Ta+ NiTa and (Ni, Pt) $_3$Ta+ NiTa+ Ni$_2$Ta, were also identified.

[Key words] Ni-Pt-Ta ternary system; diffusion layers; phase equilibria; isothermal section

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1 INTRODUCTION

The nickel-based superalloys are the most widely used high-temperature structural materials for manu-facturing aeronautical engines, gas turbines, and rocket engines. Compared with the iron-based high-temperature alloys, the advantages of the nickel-based superalloys lie in higher operating temperatures, bet-ter microstructural stability, less fractions of detri-mental phases, and better oxidation and thermal-etching resistance. Their excellent properties can be ascribed considerably to the solution strengthening and precipitation strengthening of γ' and γ'' phases. A lot of research has been undertaken on the process-ing microstructures and properties, and the most im-portant achievement is the development and applica-tion of the directionally-solidified single crystal blades[1]. Many trace elements such as Pt, Ta, Hf, Re and Nb are added into the nickel-based alloys so as to further improve their comprehensive properties, and Ta and Pt are regarded as most useful addi-tives[2].

Nash et al[3, 4] made a detailed thermodynamic evaluation on the Ni-Ta and Ni-Pt binary systems based on the previous work. Recently, the amor-phous alloys with excellent thermal stability forming between VB and VIII group elements have drawn more and more attentions[5~7]. Kaufman[8], Ansara et al[9] and CUI et al[10] experimentally measured and thermodynamically optimized the phase diagram of the Ni-Ta binary system, respectively. Giessen et al[11] determined the Pt-rich Pt-Ta phase diagram by means of metallograph and X-ray diffractometry based on the previous work.

Although there is a lot of work concerning the Ni-Ta, Ni-Pt and Pt-Ta binary system, few reports can be found on the Ni-Pt-Ta ternary system. In this work, the authors aim to determine the isothermal section of the Ni-Pt-Ta ternary system at 1 173 K by means of the diffusion triple technology, consequently further understand the phase relations in this system.

2 EXPERIMENTAL

The procedures of the diffusion couple technolo-gy can be described as follows[12, 13].

1) Different metals or nonmetals are bonded to-gether and annealed at a high temperature for a long time, as a result there form diffusion layers at the in-terfaces among the different elements. The diffusion layers are just the phases which exist in the systems at this temperature.

2) The phase relations can be identified by ana-lyzing the compositions of the diffusion layers after cooling the diffusion couples.

The raw materials for preparing Ni-Pt-Ta diffu-sion triple in this study are 99. 9% nickel ingot (5 mm × 10 mm × 10 mm), 99. 99% platinum ingot (5 mm × 5 mm × 10 mm) and 99. 9% tantalum ingot (5 mm × 5 mm × 10 mm). The schematic diagram of construction of the Ni-Pt-Ta diffusion triple is shown in Fig. 1. The chemical compositions of the equilibri-um phases were determined by the electron micro-probe analysis, then the phase relations were studied, and finally the isothermal section was established.

3 RESULTS AND DISCUSSION

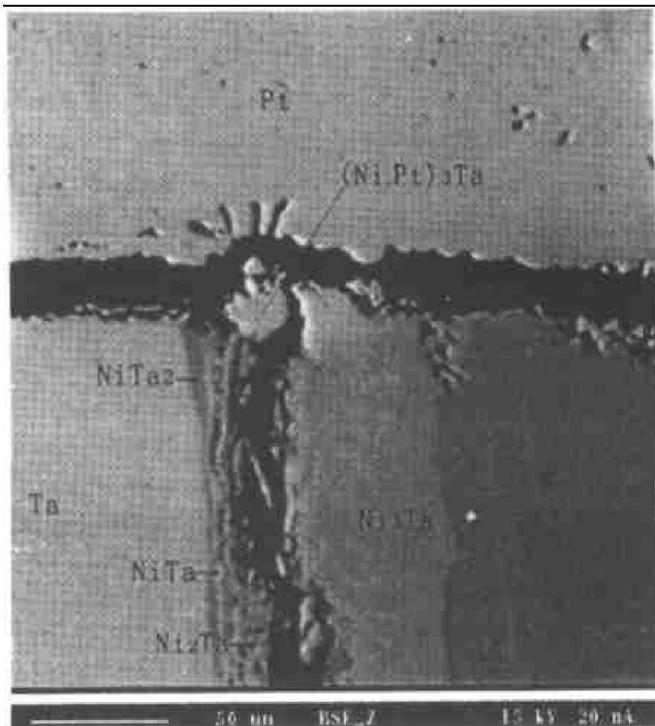The back-scattered electron image of the Ni-Pt-
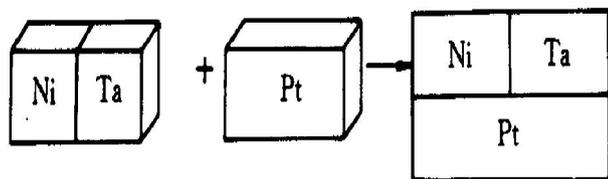
Fig. 1 Schematic diagram of construction of Ni-Pt-Ta diffusion triple

Ta diffusion triple annealed at 1 173 K is shown in Fig. 2. The chemical compositions of the equilibrium phases at the tie lines and tie triangles are listed in Table 1. It is clear from Fig. 2 that in the Ni-Pt-Ta diffusion triple annealed at 1 173 K, there occur four diffusion layers between nickel and tantalum. Referring to Fig. 2 and the experimental data in Table 1, it is initially identified that the compounds in the four diffusion layers are $NiTa_2$, $NiTa$, Ni_2Ta and Ni_3Ta, respectively. Similarly, it is found that there are two diffusion layers forming between the platinum and the tantalum, namely Pt_3Ta and Pt_2Ta. Nickel and platinum are completely soluble, thus no diffusion layers are formed.

Table 1 Tie lines and tie triangles of Ni-Pt-Ta diffusion triple determined by EMPA

(mole fraction, %)

	Ni	Pt	Ta	Ni	Pt	Ta
(Pt)/(Ta)	0	98.80	1.20	0.23	0	99.77
	9.62	90.35	0.04	0.67	0	99.33
(Ta)/NiTa₂	0.76	0	99.24	32.02	0	67.98
	6.99	0	93.01	31.74	0	68.26
NiTa₂/NiTa	32.02	0	67.98	47.27	0.02	52.70
NiTa/Ni₂Ta	49.55	0	50.45	65.29	0	34.71
Ni₂Ta/Ni₃Ta	68.52	0	31.48	71.52	0	28.48
	76.05	0	23.94	88.64	0	11.56
Ni₃Ta/(Ni)	75.31	0	24.69	86.81	0	13.19
	76.10	0	23.90	88.32	0.06	11.62
(Ni)/(Pt)	99.80	0.18	0.02	22.86	77.14	0
	12.27	62.74	24.99	21.51	52.91	25.58
(Ni, Pt)₃Ta	13.50	62.12	24.38	21.13	54.58	24.28
	37.90	36.86	25.24	25.71	49.45	24.84
	50.81	24.63	24.56	29.20	45.65	25.17

Based on the experimental data in Table 1, a series phase equilibrium tie lines and tie triangles can be drawn. Referring to Fig. 2, the isothermal section of the Ni-Pt-Ta ternary system at 1 173 K can be established by connecting the boundary lines of different equilibrium phase fields, as shown in Fig. 3. There are four three-phase fields in this plot, namely Pt_2Ta+

Fig. 2 Back-scattered electron image of Ni-Pt-Ta diffusion triple annealed at 1 173 K
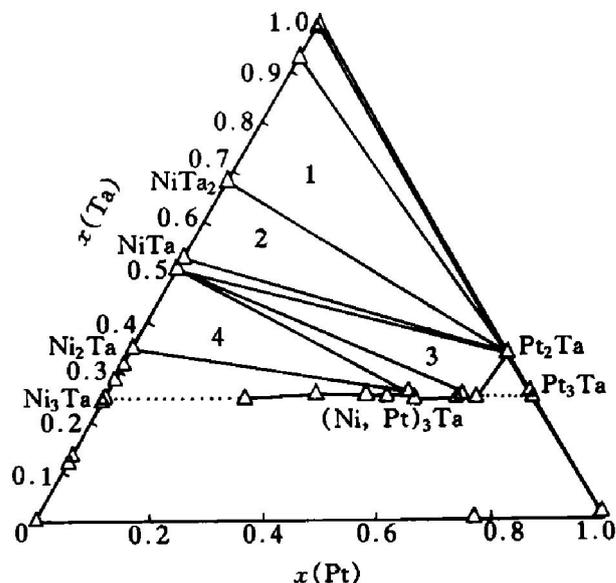
Fig. 3 Experimental isothermal section of Ni-Pt-Ta system at 1 173 K

$(Ta)+ NiTa_2$, $Pt_2Ta+ NiTa_2+ NiTa$, $Pt_2Ta+ (Ni, Pt)_3Ta+ NiTa$ and $(Ni, Pt)_3Ta+ NiTa+ Ni_2Ta$.

It can also be seen from Fig. 3 and Table 1 that the solubility of platinum in Ni-Ta compounds is very small, but that of Pt in Ni_3Ta or Ni in Pt_3Ta is very large. Because the crystal structures and lattice parameters of Ni_3Ta and Pt_3Ta are almost the same (as shown in Table 2), it can be deduced that there forms a linear compound $(Ni, Pt)_3Ta$ between Ni_3Ta and Pt_3Ta.

Additionally, no Ni_8Ta phase is found in the Ni-Pt-Ta diffusion triple under the test conditions. In order to prove whether this compound exists, the composition from the interface between nickel and

Ni₃Ta to pure nickel side is continually determined, as listed in Table 3. It is found that the content of tantalum decreases from 11. 62% to 0. 23% (mole fraction) continually, and no abrupt change happens. Therefore, a conclusion can be drawn that no Ni₈Ta compound but the solid solution of nickel is formed at 11. 62% Ta.

Table 2 Comparison of crystal structures and lattice parameters between Ni₃Ta and Pt₃Ta[11, 14]

Phase	Crystal structure	Space group
Ni₃Ta	Cu₃Ti	Pmmm
Pt₃Ta	Cu₃Ti	Pmmm

Phase	$a/$ nm	$b/$ nm	$c/$ nm
Ni₃Ta	0. 512 2	0. 423 5	0. 452 2
Pt₃Ta	0. 553 8	0. 456 0	0. 487 4

Table 3 Composition change from Ni/ Ni₃Ta interface to pure nickel

(mole fraction, %)

Position No.	Ni	Pt	Ta
1	76. 10	0	23. 90
2	88. 32	0. 06	11. 62
3	88. 95	0. 02	11. 02
4	88. 95	0. 01	10. 04
5	90. 78	0. 02	9. 20
6	91. 56	0. 01	8. 43
7	91. 40	0. 07	8. 43
8	92. 68	0. 07	8. 54
9	93. 59	0. 05	6. 36
10	94. 46	0. 08	5. 46
11	95. 37	0. 08	4. 55
12	95. 97	0. 13	3. 89
13	96. 14	0. 10	3. 77
14	97. 61	0. 04	2. 35
15	98. 50	0. 15	1. 35
16	99. 09	0. 12	0. 79
17	99. 54	0. 05	0. 41
18	99. 72	0. 05	0. 23

4 CONCLUSIONS

1) The phase relations of Ni-Pt-Ta ternary system at 1 173 K are determined. Four three-phase fields and four binary compounds are identified.

2) There forms a linear compound (Ni, Pt)₃Ta with small solubility between Ni₃Ta and Pt₃Ta.

3) In the Ni-Ta binary system, no Ni₈Ta compound forms under the test conditions.

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