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1373K isothermal section of phase diagram for Nb–W–Zr ternary system*

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The isothermal section of the Nb–W–Zr system at 1373K has been successfully measured by means of electron probe microanalysis (EPMA) on diffusion couples. This isothermal section includes two single-phase regions, "α" and (W, Nb)$_2$Zr, and one two-phase region "α" + (W, Nb)$_2$Zr. The maximum solid solubility of Nb in (W, Nb)$_2$Zr is 12.23at.% Nb.

Keywords: diffusion-couple, phase diagram, Nb–W–Zr
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1. Introduction

With the progress of science and culture, the study of outer space becomes the focus of all countries. The country that possesses advanced space power systems becomes dominant in the outer space. However, the space power requirement for future missions ranges from a few kilowatts to megawatts of electricity.[1] So, materials with excellent properties are needed. The refractory metals are some of those with good high-temperature, creep and creep-rupture properties.[1] This makes it necessary to study related phase diagrams.

As the three important elements of refractory metals, Nb, W and Zr have been studied intensively for some years. The information on phase diagrams for Nb–W, Nb–Zr, and W–Zr binary systems is available in the literature. It was reported that there was an intermetallic compound with the composition of W_2Zr in the W–Zr system,[2] a solid solution called "α" in the Nb–W system, and a solid solution with the same structure of "α" in the Nb–Zr system.[3]

For the Nb–W–Zr ternary system, some incomplete observations were made at 1373K previously, but doubts still remain regarding whether there is a solubility of Nb in W_2Zr at 1373K. So, a diffusion couple was adopted in the present study in order to determine whether or not a compound phase of Nb–W–Zr can exist in the temperature range considered.

2. Experiment

The ternary diffusion couples used in this work were prepared from the elemental components with the following purities, in as-ingot Nb99.8, W99.6 and Zr99.9. These components were assembled into a T-shaped diffusion couple (shown schematically in Fig.1). The technique of preparing the specimens is given in Ref.[4]. The assembled couple was then sealed in a quartz tube containing argon gas at a pressure of 0.13Pa followed by diffusion annealing at 1373K for 255h to produce local equilibrium interfaces.[5]

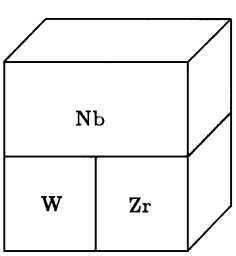


Fig.1. Construction of a Nb–W–Zr diffusion couple.

The ternary diffusion couple was analysed by optical microscopy and electron probe microanalysis (EPMA). Before undertaking the former observation,

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the couple was ground and polished. The etchant composed of HF 1%, $HNO_3$3%, HC1 1.5% and H_2O 94.5% was used to make observation easier. For EPMA, the standards for Nb, W and Zr elements were taken from parts of the corresponding components far away from the diffusion regions of the couple.

3. Results and discussion

Figure 2 shows the microstructures of the diffusion regions in the couple. The schematic chart of the couple is presented in Fig.3. Table 1 lists the results of the microprobe measurements. These data in Table 1 were taken from the couple along the phase boundary. According to these data, a tentative isothermal section of the phase diagram for Nb–W–Zr ternary system at 1373K is drawn and presented in Fig.4. This isothermal section consists of an "α" solid solution, an intermetallic compound phase and a two-phase region. The composition of the intermetallic compound phase is (W, $Nb)_2Zr$. The intermetallic phase results from some W atoms in W_2Zr replaced by Nb atoms due to the similarity in atomic size and chemical properties of W and Nb. So, the crystal structure of (W, $Nb)_2Zr$ remains bcc. The maximum solubility of Nb in the (W, $Nb)_2Zr$ is approximately 12.23at%. For clarity, the composition ranges and the maximum solubility in the intermetallic compound (W, $Nb)_2Zr$ are summarized in Table 2.

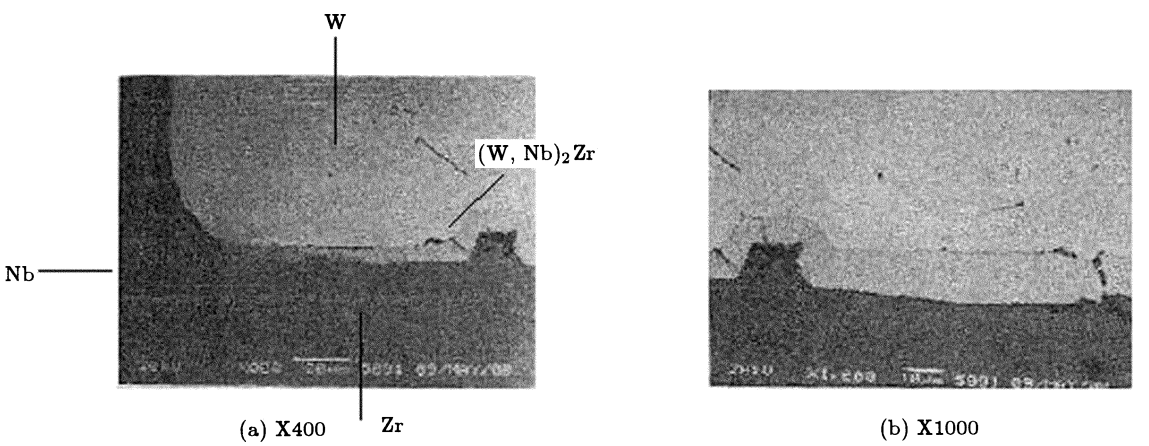


Fig.2. Microstructures of the diffusion regions of the couple annealed at 1373K for 255h.

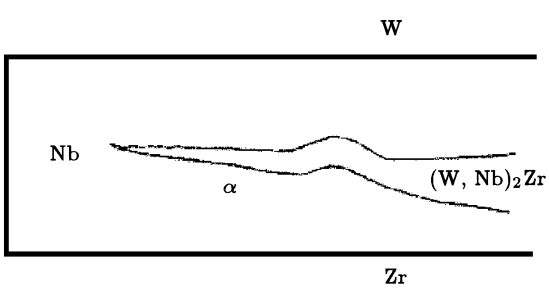


Fig.3. Chart of a Nb–W–Zr diffusion couple after heat-treatment The areas indicated illustrate the photograph corresponding to Fig.2.

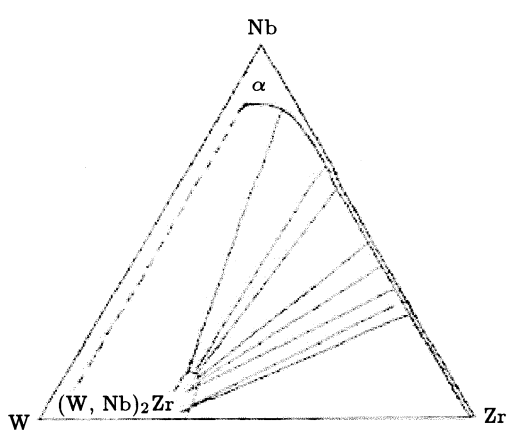


Fig.4. The isothermal section of the phase diagram of Nb–W–Zr ternary system at 1373K.

Table 1. Experimental tie lines determined by EPMA on the Nb–W–Zr specimen.

α/(W, Nb)$_2$Zr equilibrium					
(W,Nb)$_2$Zr			α		
Nb	W	Zr	Nb	W	Zr
0.46	64.39	35.15	0.02	97.28	2.72
1.41	62.62	35.96	0.18	97.57	2.26
1.89	62.56	35.55	9.75	0.28	89.97
8.84	57.42	33.74	11.69	0.34	87.97
9.34	55.81	34.85	20.66	0.55	78.79
10.05	58.90	31.04	22.75	3.80	73.46
10.47	59.12	30.41	28.08	1.30	70.62
10.97	58.10	31.02	31.27	1.15	67.58
11.42	57.15	31.43	34.53	1.18	64.39
11.57	53.48	34.95	41.92	0.08	58.00
11.85	54.19	33.96	56.71	2.04	41.25
11.86	54.29	33.85	63.16	2.27	34.56
12.23	56.55	31.22	80.48	4.08	15.44

Table 2. Summary of the composition range and maximum solubility of all phases in the 1373k section of phase diagram for the Nb–W–Zr ternary system determined by EPMA.

	Composition/at%			Maximum Solubility/at%		
Phase	Nb	W	Zr	Nb	W	Zr
(W,Nb)$_2$Zr	53.48–64.39			12.23		

From Table 2 we can safely conclude that there is a region of ternary compound phase, but the phase boundary of this phase is not very accurate due to the restriction of the laboratory's facilities.

4. Conclusions

(1) The isothermal section of the phase diagram for the Nb–W–Zr ternary system at 1373K has been determined. This section consists of two single-phase regions, "α" and (W, Nb)$_2$Zr and one two-phase region, "α" + (W,Nb)$_2$Zr.

(2) The intermetallic compound (W,Nb)$_2$Zr has been observed in the present study. The maximum solubility of Nb in (W,Nb)$_2$Zr is approximately 12.23at%.

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