Chemistry

1960

SovietRxiv

Fig. 1. Microstructure of an alloy with 90 wt.% (71.4 at.%) rhenium, 500×. a —as-cast ($\alpha + \sigma$); b —annealing at 1500°, 5 h. $\alpha + (\alpha + \beta)$

Figure 1: Fig. 1. Microstructure of an alloy with 90 wt.% (71.4 at.%) rhenium, 500×. a —as-cast ($\alpha + \sigma$); b —annealing at 1500°, 5 h. $\alpha + (\alpha + \beta)$

Abstract

Full Text

Chemistry

M. A. TYLKINA, K. B. POVAROVA, and E. M. SAVITSKII

THE SIGMA PHASE IN THE RHENIUM-VANADIUM SYSTEM

(Presented by Academician I. P. Bardin, 2 XII 1959)

The sigma phase, as is known, is a metallic compound with a structure isomorphic to β-U and has a tetragonal lattice with 30 atoms in the unit cell. The sigma phase occurs in alloys of transition metals of the VA–VIA subgroups of D. I. Mendeleev' s periodic system with transition metals of groups VIIA and VIII. Sigma phases are characterized by high hardness—of the order of 1200-1500 kg/mm^2 by Vickers.

Fig. 1. Microstructure of an alloy with 90 wt.% (71.4 at.%) rhenium, 500×. *a* —as-cast ($\alpha + \sigma$); *b* —annealing at 1500°, 5 h. $\alpha + (\alpha + \beta)$

According to literature data and our experimental data, rhenium (a metal of the VIIA subgroup) forms σ-phases with transition metals of the IVA subgroup —zirconium; of the VA subgroup—niobium, tantalum; of the VIA subgroup—chromium, molybdenum, tungsten; of the VIIA subgroup—manganese; and of group VIII—iron, with the size factor varying from +16.6% (Zr) to −8% (Fe). For σ-phases in systems with rhenium, an electron concentration of about 6.6–7.6 electrons/atom is characteristic ([1]-[9]). On the basis of the above data, especially with respect to Nb and Ta, it could be assumed that rhenium should also form a σ-phase with the element of the VA subgroup—vanadium; however, according to the data of work ([1]), no intermediate phases were found in the rhenium-vanadium system.

As a result of our work on constructing the phase diagram of the vanadium-rhenium system ([10]), it was established that the system contains a σ-phase with a narrow homogeneity range at a rhenium content of ~75 at.% (VRe_3). This phase forms by a peritectic reaction between the melt and the rhenium-based solid solution at 2490°. The microhardness of the σ-phase, measured on a PMT-3 instrument under a load of 100 g, is ~2000 kg/mm^2.

To establish the temperature interval of existence of the σ-phase, a series of high-temperature anneals of cast alloys was carried out (1750°, 7 h; 1500°, 5 h; 1000°, 450 h). The X-ray study was conducted in an RKD-type camera using CrKα radiation. According to X-ray structural and microstructural studies, eutectoid decomposition of the σ-phase at 1500° was established, with formation of a mixture of two solid solutions: vanadium-based (α) and rhenium-based (β) (Fig. 1a, b).

On the X-ray pattern for the cast alloy, a system of lines characteristic of σ-phases is observed (Table 1); calculation of the lattice parameters gave the values $a = 9.36$ Å, $c = 4.86$ Å, $c/a = 0.52$.

Table 1

hkl	Intensity	Zr—Re $\sin\theta$	Zr—Re $d \times 0.972$ Å	V—Re $\sin\theta$	V—Re $d \times 1.016$ Å	Nb—Re $\sin\theta$	Nb—Re $d \times 1.083$ Å	Ta—Re $\sin\theta$	Ta—Re $d \times 0.986$ Å
112 410	s.	0,4483	2,340	0,5030	2,309	0,541	2,294	0,4884	2,305
330	med.	0,4658	2,257	0,5180	2,243	0,551	2,247	0,5046	2,260
202	v. weak	0,4775	2,204	0,5299	2,193	0,563	2,202	0,5108	2,195
212 420	weak	0,4909	2,163	0,5439	2,137	—	—	0,5294	2,132
411	s.	0,5109	2,062	0,5548	2,093	0,590	2,098	0,5377	2,101
331	med.	0,5215	2,021	0,5678	2,048	—	—	0,5655	2,042
a, Å		10,12		9,36		8,75		9,67	
c, Å		5,42		4,86		4,06		4,97	
c/a		0,535		0,52		0,52		0,52	

hkl	Intensity	Cr—Re $\sin\theta$	Cr—Re $d \times 1.037$ Å	Mo—Re $\sin\theta$	Mo—Re d	W—Re $\sin\theta$	W—Re $d \times 1.003$ Å	Mn—Re $\sin\theta$	Mn—Re $d \times 1.044$ Å	Fe—Re $\sin\theta$	Fe—Re $d \times 1.058$ Å
112 410	s.	0,5120	2,316	0,4957	2,308	0,497	2,308	0,5169	2,309	0,5234	2,311
330	med.	0,5275	2,247	0,5089	2,247	0,512	2,250	0,5312	2,248	0,5390	2,245
202	v. weak	0,5385	2,202	0,5194	2,202	0,524	2,189	0,5416	2,205	0,5505	2,197

hkl	Intensity	Cr—Re $\sin\theta$	Cr—Re $d \times 1.037$ Å	Mo—Re $\sin\theta$	Mo—Re d	W—Re $\sin\theta$	W—Re $d \times 1.003$ Å	Mn—Re $\sin\theta$	Mn—Re $d \times 1.044$ Å	Fe—Re $\sin\theta$	Fe—Re $d \times 1.058$ Å
212 420	weak	0,5530	2,143	0,5338	2,142	0,535	2,143	0,5569	2,143	0,5644	2,144
411	s.	0,5675	2,090	0,5454	2,097	0,547	2,097	0,5707	2,092	0,5757	2,101
331	med.	0,5800	2,044	0,5594	2,044	0,560	2,048	0,5858	2,039	0,5919	2,045
a, Å		9,23		9,54		9,54		9,14		9,02	
c, Å		4,80		4,96		4,97		4,75		4,69	
c/a		0,52		0,52		0,52		0,52		0,52	

Table 1 presents comparative data from the calculation of X-ray patterns of σ-phases with Cr$K\alpha$ radiation in the systems of rhenium with zirconium (⌒4), vanadium, niobium (⌒5), tantalum, chromium (⌒6), molybdenum ([7],8), tungsten (⌒9), manganese, and iron (⌒8).

On comparison, attention is drawn to a certain difference of the phase in the Zr—Re system, which we assigned to a type related to σ-phases, from the other σ-phases. This difference is probably explained by the fact that formation of σ-phases is not characteristic of metals of subgroup IVA, and the appearance of a σ-phase in the rhenium—zirconium system may be regarded as an exception.

In addition, an interesting fact is the formation of σ-phases in the system of rhenium with manganese and iron, elements of groups VIIA and VII (⌒8), which indi-

indicates the anomalous behavior of rhenium in comparison with metals of other groups.

Baikov Institute of Metallurgy
Academy of Sciences of the USSR

Received
1 XII 1959

CITED LITERATURE

[1] P. Greenfield, P. A. Beck, J. Metals, 8, No. 2 (1956).
[2] A. G. Knarfton, J. Inst. Metals, 87, No. 1 (1958).
[3] Ya. Nemets, V. Tzhebyatovskii, *Biull. Polsk. Akademii nauk*, ser. 3, 4, No. 9 (1956).
[4] E. M. Savitskii, M. A. Tylkina, I. A. Tsygano-va, *Atomic Energy*, 7, issue 3 (1959).

[5] E. M. Savitskii, M. A. Tylkina, K. B. Povarova, *Atomic Energy*, 7, issue 5 (1959).
[6] E. M. Savitskii, M. A. Tylkina, K. B. Povarova, *ZhNKh*, 4, issue 8 (1959).
[7] E. M. Savitskii, M. A. Tylkina, K. B. Povarova, *ZhNKh*, 4, issue 2 (1959).
[8] Ch. V. Kopetskii, V. Sh. Shekhtman, N. V. Ageev, E. M. Savitskii, *DAN*, 125, No. 1 (1959).
[9] E. M. Savitskii, M. A. Tylkina, L. L. Shul' kina, *News of the Academy of Sciences of the USSR, Metallurgy and Fuel*, No. 3 (1959).
[10] E. M. Savitskii, M. A. Tylkina, K. B. Povarova, *Phase diagram of alloys of the vanadium–rhenium system* (report), Institute of Metallurgy, Academy of Sciences of the USSR, 1959.

Note: Figure translations are in progress. See original paper for figures.