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Abstract

Full Text

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On the Quasibinary Character of the System: Six-Component Nickel Solid Solution + Titanium Carbide

(Presented by Academician I. I. Chernyaev, 11 X 1957)

The absence of general principles in the study of multicomponent metallic systems and the difficulties of representing them visually require the development of new rational methods for their investigation.

The tendency of metals to form solid solutions, compounds, and solid solutions based on these compounds leads to the fact that in multicomponent systems considerably fewer phases are formed than might be expected from the number of participating components.

The presence of chemical affinity between elements and a certain degree of activity of the reacting elements in a multicomponent system make it possible to reduce the study of the latter to the investigation of equilibrium between a limited number of phases (two-, three-, and four-phase equilibria). Some questions of the theory of state diagrams of such multicomponent metallic systems are considered in work ⁽¹⁾.

In this connection, in a number of cases the study of certain multicomponent systems can be reduced to the investigation of three-phase equilibrium: multicomponent liquid solution *leftrights* multicomponent solid solution + metallic compound.

As an example we took an 8-component nickel system Ni–Cr–W–Mo–Nb–Ti–Al–C, in which, with a definite combination of components, a three-phase equilibrium can be obtained: 8-component liquid solution *leftrights* 8-component solid solution + TiC compound or its solid solution.

Table 1

Heat of formation of carbides

Fig. 1. Fusibility diagram of the system: 6-component nickel solid solution (γ_6)–titanium carbide (TiC). Crosses indicate the solubility limits according to X-ray structural analysis data.

Figure 1: Fig. 1. Fusibility diagram of the system: 6-component nickel solid solution (γ_6)–titanium carbide (TiC). Crosses indicate the solubility limits according to X-ray structural analysis data.

Carbide	Ni ₃ C	Fe ₃ C	Mo ₂ C	WC	TaC	Cr ₄ C	NbC	VC	TiC
Heat of formation – ΔH kcal/mol	–9.2	–5.8	–4.0	+8.4	+9.0	+16.0	+19.0	+28.0	+57.0

On the basis of data on the heats of formation of the carbides of nickel, chromium, tungsten, molybdenum, niobium, and titanium (see Table 1), it is possible to predict in advance the course of the reaction in such an 8-component nickel system containing the above-mentioned elements, and to assume that titanium carbide will be formed preferentially.

Titanium carbide is formed with the greatest thermal effect and is more stable than all the possible carbides in the system under study.

To verify the above assumptions, the chemical interaction with titanium carbide of a 6-component nickel solid solution (containing Cr, W, Mo, Nb, and Al), taken as the initial phase, was studied, and the phase equilibrium in this 8-component system was established.

The composition of the initial 6-component nickel solid solution was chosen as follows: Ni 82%, Cr 7%, W 3%, Mo 3%, Al 3%, and Nb 2%.

For the investigation, alloys were prepared consisting of the initial 6-component nickel solid solution to which titanium carbide was added in amounts from 0 to 95%.

Alloy specimens were prepared by melting in an induction furnace (up to 15% TiC) and by powder metallurgy (from 25% to 95% TiC).

For the study of the alloys, thermal, metallographic, X-ray, and intermetallic methods of analysis were used. In addition, the hardness of nickel-rich alloys was studied after quenching from 1250, 1200, and 1000°.

Fig. 1. Fusibility diagram of the system: 6-component nickel solid solution

(γ_6)—titanium carbide (TiC). Crosses indicate the solubility limits according to X-ray structural analysis data.

To determine the temperature interval of crystallization of alloys containing from 0 to 15% TiC, thermal analysis was carried out. Cooling curves were recorded on an N. S. Kurnakov pyrometer using a platinum—platinum-rhodium thermocouple.

The fusibility diagram of the system 6-component nickel solid solution—titanium carbide is given in Fig. 1. In it the 6-component nickel solid solution is denoted by γ_6 . As can be seen from this diagram, the nickel solid solution γ_6 with titanium carbide crystallizes according to the eutectic type, with limited solubility of the phases*. The liquidus line decreases from the melting temperature of γ_6 , 1400°, to the eutectic temperature, 1345°, at a TiC content of 5%. Crystallization of the alloys studied occurs within a small temperature interval (10–20°).

Microstructural investigation of cast and quenched alloys confirms the eutectic structure of the corresponding alloy compositions.

To determine the solubility of TiC in the 6-component nickel solid solution, alloys containing from 0 to 10% TiC were quenched at temperatures of 1300, 1250, 1200, and 1000°. The holding time at the indicated temperatures was 100 hours.

The determination of solubility was carried out by metallographic and X-ray methods.

According to the data obtained, the solubility of TiC in the 6-component nickel solid solution varies with temperature. At 1250° the solubility of TiC is 1.4%, at 1200° it is 0.5%, and at 1000° it is about 0.1% TiC.

In alloys containing more than 5% TiC (hypereutectic), the first phase to crystallize is titanium carbide, the large crystals of which (of cubic form) are embedded in the eutectic.

In an alloy with 50% TiC, after quenching from 1300°, large TiC crystals surrounded by eutectic are observed.

From alloys containing 1.0, 4, and 7.5% TiC, only one carbide phase was isolated by selective dissolution of the solid solution γ_6 .

Preliminary chemical analysis of the isolated phase indicates the presence in it, along with titanium and carbon, of niobium, molybdenum, tungsten, chromium, and aluminum. Evidently, these elements enter into the solid solution of the car-

* Although the cooling curve of an alloy of eutectic composition shows crystallization at an almost constant temperature, the authors believe that there can be no point of nonvariant equilibrium here.

titanium carbide. The composition of this phase changes depending on the composition of the initial alloy.

According to X-ray structural analysis, this phase has a face-centered cubic lattice of the TiC type. The lattice parameter varies from 4.38 to 4.33 kX.

Such a change in the lattice parameter of the phase can be explained by a change in the composition of the phase depending on the ratio of the components of the initial alloy. As the content of the titanium carbide introduced increases, the percentage of titanium in this phase increases while an approximate atomic ratio of metals (Ti, Nb, Mo, W, Cr, and Al) to carbon of 1 : 1 is maintained.

On the basis of the study carried out, the possibility has been demonstrated of studying multicomponent metallic systems by the method of bringing them to equilibrium among a limited number of phases.

By methods of thermal analysis, metallographic analysis, and X-ray investigation, a phase diagram has been constructed for the quasibinary system: six-component nickel solid solution (γ_6)—titanium carbide (TiC). It shows the eutectic character of crystallization of the phases with mutually limited solid solutions of these phases.

The solubility of titanium carbide in the six-component nickel solid solution has been determined. At 1300° it is equal to 1.9% TiC. With decreasing temperature, the solubility of TiC decreases and is, respectively, 1.4, 0.55, and 0.15% TiC at temperatures of 1250, 1200, and 1000°.

In the quasibinary system studied, the presence of only two phases has been established: the γ_6 solid solution based on nickel and the phase based on titanium carbide.

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1. I. I. Kornilov, *Reports at the Conference on the Study of Phase Diagrams of Metallic Systems*, Publishing House of the Academy of Sciences of the USSR, 1956, p. 10.

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

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