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Abstract

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INVESTIGATION OF METALLIC COMPOUNDS FORMED DURING THE INTERACTION OF A FIVE-COMPONENT NICKEL SOLID SOLUTION WITH TITANIUM CARBIDE

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A number of works have been described in the literature devoted to the investigation of the interaction of refractory compounds of the carbide type with metallic solid solutions ([1,2]).

Using the method of intermetallic analysis, the authors established the presence and composition of metallic compounds in alloys consisting of a six-component nickel solid solution with titanium carbide ([3]). I. I. Kornilov, L. I. Pryakhina, and O. V. Ozhimkova are studying the interaction of a five-component nickel solid solution with titanium carbide in alloys not containing niobium. In the present work the metallic compounds arising in the specified alloys were studied.

In the system under study, the most probable formation is that of titanium carbide or a phase based on this carbide. Other metal carbides in this case may enter into solid solutions of titanium carbide. The capacity of carbides to form solid solutions has long been noted by many authors ([4–6]). Carbides with the same crystal structure (isomorphous) always form a continuous series of solid solutions if the difference in lattice periods is not especially large. Carbides of metals of Groups IV and V of the periodic system, on the one hand, and carbides of metals of Group VI, owing to the difference in crystal structure, can give only limited mutual solubility.

Alloy specimens, smelted by L. I. Pryakhina and O. V. Ozhimkova, were used in the heat-treated state according to the following schedule: quenching from 1200° with cooling in water, after holding at this temperature for 115 hours. To check whether the alloys under investigation contained an intermetallic phase, electrochemical dissolution of the alloys was carried out in an electrolyte previously proposed by us and consisting of 50 ml HNO_3, 20 ml $HClO_4$ per 1000 ml of water, at a current density of 0.1 A/cm^2 ([7]). As our experiments showed, all the alloys investigated contain no intermetallic phase.

Isolation of the carbide phase was carried out in an electrolyte consisting of

100 ml HCl (1.19), 100 g citric acid, 5 g succinic acid, and 1000 ml water, at a current density of 0.5 A/cm^2 and with ice cooling ([7]). In the alloy containing 0.1% TiC, no separation of excess phases was observed, because an alloy of this composition corresponds to a homogeneous solid solution based on nickel. Phase analysis of alloys containing 1.00; 4.00; 8.00% TiC showed the presence in these alloys of a carbide phase of complex composition.

The results of chemical analysis of the isolated carbide powders are given in Table 1. It is interesting to note that only traces of nickel and insignificant amounts of aluminum are present in the carbide powders. This indicates that these two elements, which form carbides less stable than Ti, W, and others, do not enter into the composition of titanium carbide. As

Table 1

Chemical composition of phases isolated from alloys of the γ_5-TiC system

TiC content in alloy, %	Experiment no.	Ti	C	W	Al	Cr	Mo	Sum	$\varepsilon\Sigma$ Me : C
1.0	24	42.99 / 38.63	12.30 / 44.07	23.20 / 5.43	1.06 / 1.69	2.70 / 2.23	17.71 / 7.94	99.96 / 99.99	$\frac{54.23}{44.07} = 1.2$
4.0	23	44.87 / 39.28	12.97 / 45.28	22.59 / 5.15	0.73 / 1.13	2.54 / 2.05	16.25 / 7.10	99.95 / 99.99	$\frac{53.58}{45.28} = 1.1$
8.0	21	46.95 / 39.73	13.66 / 46.15	20.96 / 4.66	0.87 / 1.31	2.19 / 1.71	15.23 / 6.44	100.23 / 100.00	$\frac{52.54}{46.15} = 1.1$

Notes. 1. The figures above the line are expressed in wt. %, those below the line—in at. %.
2. Traces of nickel were detected in all phases.

As is evident from the data presented in Table 1, titanium predominates in the carbide phase. Its content in atomic percent is 39–40%. Consequently, the basis of the carbide phase is titanium carbide. The metals in the form of carbides are part of the solid solution of titanium carbide. The total content of the carbide-forming elements Ti, W, Mo, and Cr in atomic percent is 52–54%, and the C content is 44–46%. Thus, the ratio of the sum of carbide-forming elements to carbon is very close to 1 : 1. In this case, obviously, the composition of the carbide precipitate may be assigned the formula of a MeC-type carbide and expressed in the form Ti (W, Mo, Cr)C.

Table 2

Proposed carbide formula	Sample, content 1.0% TiCMe content in carbide phase, at. %	Sample, content 1.0% TiCRequired amount (by formula) C, at. %	Sample, content 4.0% TiCMe content in carbide phase, at. %	Sample, content 4.0% TiCRequired amount (by formula) C, at. %	Sample, content 8.0% TiCMe content in carbide phase, at. %	Sample, content 8.0% TiCRequired amount (by formula) C, at. %
TiC	38.63	38.63	39.28	39.28	39.77	39.77
WC	5.43	5.43	5.15	5.15	4.62	4.62
MoC	7.94	7.94	7.10	7.10	6.44	6.44
Cr_4C	2.23	0.56	2.05	0.51	1.71	0.43
Total		52.56		52.04		51.26
Found		44.07		45.28		46.15
Deficit in C		8.49		6.76		5.11

Table 3

TiC content in specimens, %	Carbides	Carbides	Carbides	Carbides
	TiC	WC	MoC	Cr_4C
1.0	77.26	10.86	15.88	2.79
4.0	78.56	10.30	14.20	2.56
8.0	79.54	9.24	12.88	2.14

According to X-ray structural analysis* the carbide phase has a cubic face-centered lattice of the TiC type with parameter $a = 4.30 \div 4.32$ kX. If the formula of the complex carbide is represented in the form of individual—

* The X-ray structural analysis was performed by A. Ya. Snetkov.

carbides TiC, WC, MoC, and Cr_4C, which form solid solutions with one another, it is possible to calculate the required (theoretical) amount of carbon (Table 2) and the content of individual carbides in the anode powders (Table 3).

Thus, it may be considered proven by the method of intermetallide analysis that, at equilibrium in the multicomponent system of the alloy compositions studied, only two phases participate: a five-component nickel solid solution and a solid solution of titanium carbide.

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