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Fig. 1

Figure 1: Fig. 1

Fig. 2

Figure 2: Fig. 2

Abstract

Full Text

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DECOMPOSITION OF SOLID SOLUTIONS OF NIOBIUM AND TITANIUM IN CHROMIUM

Chromium-based solid solutions, which are of interest as heat-resistant materials, have been little studied by X-ray diffraction.

Presented below are the results of an investigation of changes in the crystal-lattice constants of solid solutions of niobium and titanium in chromium, which, according to the data of the present work, undergo complete decomposition. The objects of the study were chromium alloys with niobium and titanium, the compositions of which, according to the literature data, lie in the solubility region on the phase diagrams of both systems (¹⁻⁶).

Fig. 1. Change in the lattice constant in chromium-based solid solutions as a function of niobium and titanium content (deformed alloys, not annealed after work hardening).

1 –Cr–Nb alloy, 2 –Cr–Ti alloy.

$\Delta a = \pm 0.001$ kX

Fig. 2. Change in the lattice constant of the deformed alloy Cr + 3.27 at.% Nb as a function of annealing temperature (holding time –1 hour).

$a_{Cr} = 2.879$ kX,

$\Delta a = \pm 0.001$ kX

Alloys containing up to 5 at.% niobium and up to 10 at.% titanium were prepared from pure metals (electrolytic twice-refined chromium and iodide niobium and titanium) by the method of crucibleless melting in the suspended state in an atmosphere of purified helium (⁷). Homogenizing annealing was carried out

in a TVV-2 furnace in purified argon. To obtain alloys in a state close to equilibrium at low temperatures, stepwise annealing was carried out according to the scheme given below:

Annealing temperature (°C)	1400	1200	1000	800	600
Holding time (hours)	24	24	48	72	96

As a result of studying the microstructure and measuring the microhardness of the heat-treated alloys, the position of the boundary of the two-phase region for Cr–Nb alloys was established between 2 and 3 at.% Nb, and for Cr–Ti alloys between 5 and 7 at.% Ti, which is in agreement with the data of works ⁽¹⁾ and ⁽⁵⁾.

To carry out the X-ray study of chromium-based solid solutions, alloy powders were obtained (the alloys were crushed in a mortar and sieved through a 320-mesh sieve). From powders of alloys not annealed after work hardening, flat specimens were prepared for X-ray examination and X-ray diffraction patterns were obtained by the back-reflection method. The X-ray diffraction patterns were recorded in vanadium radiation; for calculating the lattice constants, the reflection from the 211 plane was used, which in radiation $\lambda_{\nu K\beta} = 2.2797$ kX is obtained at an angle $\theta \approx 76^\circ$. Gold and pure chromium served as standards.

The change in the lattice constants of the solid solutions as a function of the Nb and Ti content is shown in Fig. 1.

From consideration of the graph it follows that the change in the course of the dependence of the lattice constants for alloys of both systems marks the position of the boundary of the two-phase region, determined in the study of the microstructure and microhardness of the alloys. The accuracy of measuring the lattice constants from X-ray diffraction patterns of deformed alloys is not high, ± 0.001 kX. During annealing of alloy powders, carried out to relieve stresses, instead of line narrowing in the X-ray diffraction patterns, decomposition of the solid solutions Cr–Nb and Cr–Ti was detected. The powders were annealed in small quartz ampoules sealed under vacuum, which in turn were sealed in larger ampoules containing a getter (titanium iodide shavings).

Decomposition in Cr–Nb alloys, noted by the displacement of lines in the X-ray diffraction patterns, is appreciable but proceeds slowly, beginning at temperatures of 820–850°; with increasing annealing temperature the rate of decomposition increases.

Figure 2 presents the change in the lattice constant of an alloy with the limiting niobium content in solid solution (3.27 at.%) as a function of annealing temperature. The annealing time at each temperature was 1 h. From consideration of the graph it is seen that, with increasing temperature, the lattice constant of the solid solution gradually decreases, almost reaching the value of the constant for pure chromium. During annealing of Cr–Ti alloy powders in the temperature

Fig. 3. Dependence of the lattice constant of the deformed alloy Cr + 7.5 at.% Ti on annealing temperature (holding during annealing 1 h). $a_{\text{Cr}} = 2.8790 \text{ kX}$,
 $\Delta a = \pm 0.001 \text{ kX}$

Figure 3: Fig. 3. Dependence of the lattice constant of the deformed alloy Cr + 7.5 at.% Ti on annealing temperature (holding during annealing 1 h). $a_{\text{Cr}} = 2.8790 \text{ kX}$, $\Delta a = \pm 0.001 \text{ kX}$

range 950–1200°, no displacement of the lines of the initial solid solution was observed in the X-ray diffraction patterns; only their intensity decreased with the simultaneous appearance of lines belonging to pure chromium (or to a solid solution whose lattice constant differs from that of chromium within the limits of measurement error).

Fig. 3. Dependence of the lattice constant of the deformed alloy Cr + 7.5 at.% Ti on annealing temperature (holding during annealing 1 h). $a_{\text{Cr}} = 2.8790 \text{ kX}$, $\Delta a = \pm 0.001 \text{ kX}$.

Figure 3 presents the change in the lattice constant of an alloy with the limiting titanium content in solid solution (7.5 at.% Ti) as a function of annealing temperature. It is seen that decomposition of titanium solid solutions in chromium occurs according to the “two-phase” type established in work ⁽⁸⁾.

Thus it has been established that deformed solid solutions based on chromium decompose upon heating, and the nature of decomposition is different for Cr–Nb and Cr–Ti alloys. Solid solutions of niobium in chromium decompose according to the usual scheme with a gradual change in the lattice constant, whereas solid solutions of titanium in chromium undergo “two-phase” decomposition. From the data presented it also follows that the solubility of titanium in chromium at 1200° and below does not exceed 0.3–0.6 at.%. Approximately the same value is also the solubility of niobium in chromium at 1000° and lower temperatures.

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