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Abstract

Full Text

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CHEMISTRY OF SOLID SOLUTIONS BASED ON TITANIUM

(Presented by Academician A. N. Frumkin, April 13, 1965)

Recently, titanium alloys have been studied very intensively. The results obtained make it possible to draw certain general conclusions regarding the parameters of its binary solid solutions with various elements.

Figure 1 presents portions of binary phase diagrams of titanium relating to primary solid solutions, their eutectics and peritectics, plotted on the table of D. I. Mendeleev' s periodic system of the elements. Solid lines show the boundaries of the fields of phase diagrams constructed from experimental data. The diagram fields lying between the solidus-liquidus lines and the lines bounding the process of transformation of β-Ti into α-Ti, constructed from experimental data, are hatched. As can be seen from Fig. 1, for 36 elements complete information is available on the boundaries of their solid solutions in α- and β-titanium, and for 10 elements partial information is available.

Fig. 2. Solubility of various elements in β- (*a*) and α-Ti (*b*) at the eutectic or peritectic temperature

The experimental data on the basis of which the generalization is made were taken from modern reference literature ([1]-[3]).

Dashed lines and the numbers in parentheses refer to unstudied systems and are the result of predictions ([4]). All concentrations in Fig. 1 and the following figures are expressed in atomic percent.

Figure 2 presents the solubilities at the eutectic temperature of various elements in α- and β-titanium. Figure 3 gives analogous dependences for the concentrations of eutectics or peritectics formed by solid solutions of both modifications of titanium with the corresponding elements and by chemical compounds closest to titanium. Both diagrams have a logarithmic scale for the concentration axis,

Fig. 3. Concentrations of eutectic or peritectic points of solid solutions of various elements in β-(a) and α-(b) Ti

Figure 2: Fig. 3. Concentrations of eutectic or peritectic points of solid solutions of various elements in β-(a) and α-(b) Ti

making it possible to reveal clearly the quantities under study over all orders of their values.

These graphs may be regarded as generalized phase diagrams that combine elements of physicochemical analysis with the periodic law and make it possible to present, in a single field, the characteristics of the set of binary titanium alloys with all elements.

As can be seen from Figs. 2 and 3, the concentrations of limiting solubilities, eutectics, and peritectics form, for both modifications of titanium, regular curves that change in accordance with the periods of the system of elements.

All the characteristics for α-titanium, as a rule, lie below the corresponding characteristics for β-titanium. Intermediate points for unstudied elements are determined with sufficient confidence by interpolation.

Interpolation for the inert gases for both modifications of titanium gives a solubility on the order of 10^{-5}%, and for the monotectic concentration 10^{-3}%.

Fig. 3. Concentrations of eutectic or peritectic points of solid solutions of various elements in β-(a) and α-(b) Ti

For vanadium, niobium, molybdenum, tantalum, and rhenium, the region of the transition of β-titanium into α-titanium is pinched out; therefore, for their solutions in α-titanium, determining the concentrations of limiting solubility, eutectic, or peritectic has no meaning.

In the diagram of Fig. 4, along the vertical axis from bottom to top on a logarithmic scale are plotted the concentrations of peritectic or eutectic points, as well as minima in systems forming continuous solid solutions for alloys of titanium and some other refractory metals. (If, in a system forming a continuous solid solution, no intermediate minimum is formed, the 100% dissolved element is taken as the minimum point.) Along the horizontal axis is plotted the relative difference in transformation temperature,

$$T_{\text{rel}} = \frac{T_0 - T_{\text{tr}}}{T_0 + 273},$$

where T_0 is the melting temperature of the base metal or the transition of one of its modifications into another; T_{tr} is the temperature of transformation (eutectic, peritectic, or minimum on the curve of continuous solid solutions).

Fig. 4. Ratio of the concentrations of eutectics, peritectics, and minima on solid-solution curves to the relative temperature difference of these transformations for α- and β-Ti, Cr, Mo, W, and V; 1a—eutectic $\omega \leq 0.1$, b—lower peritectic $\omega \leq 0.1$; 2a—eutectic $0.99 > \omega > 0.1$, b—lower peritectic $0.99 > \omega > 0.1$; 3—solution; 4—upper peritectic

Figure 3: Fig. 4. Ratio of the concentrations of eutectics, peritectics, and minima on solid-solution curves to the relative temperature difference of these transformations for α- and β-Ti, Cr, Mo, W, and V; 1a—eutectic $\omega \leq 0.1$, b—lower peritectic $\omega \leq 0.1$; 2a—eutectic $0.99 > \omega > 0.1$, b—lower peritectic $0.99 > \omega > 0.1$; 3—solution; 4—upper peritectic

In the right-hand part of the diagram are located the points corresponding to eutectics, minima of solid solutions, and lower peritectics, for which the temperature of the peritectic transformation is below the melting point of titanium. In the left-hand part are located the points corresponding to upper peritectics, for which the transformation temperature lies above the melting point of titanium and T_{rel} has a negative value.

The position of a point on the diagram also depends on the distribution coefficient

$$\omega = C_{\text{tv}}/C_{\text{zh}},$$

where C_{tv} is the solubility of the element in the solid metal at the eutectic or peritectic temperature; C_{zh} is the solubility of the element in the liquid metal at the eutectic or peritectic temperature.

The smaller the value of the distribution coefficient, the lower the concentration of the eutectic or peritectic at its given relative tem-

literature. In the case of a continuous solid solution, $\omega = 1$ either at the minimum point or at the melting temperature of the corresponding element, which may be below the melting point of the base metal (right-hand part of the diagram) or above it (left-hand part of the diagram).

The adopted system of construction makes it possible to generalize data relating both to different modifications of one and the same metal (titanium) and to different metals.

Fig. 4. Ratio of the concentrations of eutectics, peritectics, and minima on solid-solution curves to the relative temperature difference of these transformations for α- and β-Ti, Cr, Mo, W, and V; 1a—eutectic $\omega \leq 0.1$, b—lower peritectic $\omega \leq 0.1$; 2a—eutectic $0.99 > \omega > 0.1$, b—lower peritectic $0.99 > \omega > 0.1$; 3—solution; 4—upper peritectic.

On the basis of the diagrams in Figs. 2, 3, and 4, predictions were made concerning the characteristics of solid solutions in titanium of elements that have not yet been investigated. The results of the predictions are plotted on the diagram in Fig. 1.

As can be seen from Fig. 1, the binary phase diagrams of titanium alloys can be divided into the following groups:

β-Ti	α-Ti	Number of diagrams
Continuous solid solution	Continuous solid solution	3
Continuous solid solution	Narrowing of the α region	4
Continuous solid solution	Eutectoid	2
Eutectic	Peritectoid	15
Eutectic	Eutectoid	41
Upper peritectic	Peritectoid	3
Upper peritectic	Eutectoid	2
Lower peritectic	Peritectoid	1
Lower peritectic	Eutectoid	4

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REFERENCES CITED

1. M. Hansen, K. Anderko, *Structures of Binary Alloys*, 1962.

2. Phase diagrams of the states of metallic systems. Edited by N. V. Ageev. All-Union Institute of Scientific and Technical Information, 1-7, 1959-1963.

3. L. I. Molchanova, *Atlas of Phase Diagrams of Titanium Alloys*, 1964.

4. B. B. Gulyaev, DAN, 164, No. 1 (1965).

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