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Abstract

Full Text

Chemistry

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Types of Phase Diagrams of Ternary Systems Based on Titanium

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

The previously established character of the chemical interaction of titanium in binary systems ([1–3]) is also valid for considering the case of the simultaneous interaction of titanium with two and a larger number of components. The chemical nature of the elements entering into reaction, their position in the periodic system, the ratio of atomic radii, and the type of crystal lattice, as was shown for titanium alloys, are reflected in the phase diagrams of binary systems ([1,3]). Undoubtedly these same factors must determine the character of the interaction of titanium in ternary metallic systems and, consequently, the type of phase diagrams of ternary systems based on it.

From the above considerations, taking into account the phase diagrams of binary systems, it is possible to demonstrate the formation of the following types of phase diagrams of ternary systems based on titanium.

1. A phase diagram of a ternary system with continuous solid solutions of the α- and β-modifications of titanium may occur under the simultaneous interaction of titanium with its analogs—zirconium and hafnium. As is known, these elements of Group IV likewise have two allotropic modifications—α and β, analogous to the modifications of titanium, which leads in the binary systems Ti—Zr, Zr—Hf, and Ti—Hf to the formation of continuous solid solutions of both the α- and β-modifications. Experimentally this ternary system has not been studied, but from the character of the interaction in the corresponding binary systems the phase diagram of the ternary system Ti—Zr—Hf may be represented in the form shown in Fig. 1. It is the only system of this type.

2. A phase diagram of a ternary system with continuous solid solutions of β-titanium and limited solid solutions of α-titanium (Fig. 2) may be obtained under the simultaneous interaction of titanium with any two of the four metals of Groups V and VI of the periodic system: V, Nb, Ta, and Mo. These elements have a small difference in atomic radii (relative to titanium) and a crystal lattice isomorphous with the lattice of β-titanium. To this type belong all six ternary phase diagrams based on titanium with the four elements listed above. At present only two systems of this type have been investigated: Ti—Nb—Mo, Ti—V—Nb ([4]).

SovietRxiv

3. A phase diagram with a eutectoid transformation of titanium-rich alloys arises when titanium interacts with elements that lower the temperature of its polymorphic transformation and cause eutectoid decomposition of the β-phase. Such elements are: H, Cu, Ag, Au, Pb, Si, Cr, W, U, Mn, Fe, Co, and the metals of the platinum group—16 elements in all. These elements are located in Groups I, IV, VI, VII, and VIII of the periodic system and form with the α- and β-modifications of titanium not only limited solid solutions, but also metallic compounds. The presence of such compounds in the corresponding binary systems makes it possible to carry out triangulation in ternary systems and to investigate independently secondary ternary systems with titanium.

The general form of the phase diagram of the 3rd type is shown in Fig. 3. There will be 120 such systems in all. These are the systems Ti—Cr—Fe, Ti—Mn—Co, and others.

Fig. 1. Ternary system with continuous solid solutions of α- and β-titanium

Fig. 2. Ternary system with continuous solid solutions of β-titanium and limited solid solutions of α-titanium

Fig. 3. Ternary system with a eutectoid transformation

Fig. 4. Ternary system with a peritectoid transformation

4. A phase diagram with a peritectic and peritectoid type of transformation for titanium-rich alloys is obtained when titanium interacts simultaneously with elements that raise the melting temperature and the polymorphic transformation temperature of titanium (C, N, O), or with elements that lower the melting temperature but raise the polymorphic transformation temperature of titanium (Al, B, Ge, Sn). The type of phase diagram with this character of component interaction is shown in Fig. 4. There are 21 systems of this type in all. These are the systems Ti—C—N, Ti—Al—Sn, and others.

5. The fifth type of phase diagram of ternary systems corresponds to the case in which one of the components forms with α- and β-titanium a continuous series of solid solutions, while the second forms continuous solid solutions only with

with β-titanium and limited with α-titanium, i.e., a combination of binary diagrams of the 1st and 2nd types takes place[1]. Such systems, for example, will be: Ti—Zr—V and Ti—Zr—Nb. The total number of ternary systems of this type is 8.

6. The sixth type of phase diagrams of ternary systems arises as a result of a combination of binary diagrams of the 1st and 3rd types, i.e., when one of the components forms continuous solid solutions with α- and β-titanium, while the second lowers the temperature of the polymorphic

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transformation of titanium and causes eutectoid decomposition of the β-phase. Example: the Ti–Zr–Cu system. The total number of ternary systems of this type is 32.

7. The seventh type of phase diagrams of ternary titanium systems occurs when one of the components forms continuous solid solutions with α- and β-titanium, while the second raises the temperature of the polymorphic transformation of titanium with a subsequent peritectic or peritectoid reaction, i.e., a combination of binary diagrams of the 1st and 4th types. Example: the Ti–Zr–Al system. The total number of such systems is 14.

8. The eighth type of phase diagrams of ternary systems is formed as a result of a combination of binary diagrams of the 2nd and 3rd types, i.e., when one of the components forms continuous solid solutions only with β-titanium, while the second lowers the temperature of the polymorphic transformation of titanium and causes eutectoid decomposition of the β-phase. Example: the Ti–V–Cu systems, etc. The total number of these systems is 64.

9. The ninth type of phase diagrams of ternary systems corresponds to the case of a combination of binary systems of the 2nd and 4th types, i.e., when one of the components forms continuous solid solutions only with β-titanium, while the second raises the temperature of the polymorphic transformation of titanium with a subsequent peritectic or peritectoid reaction. This includes the systems Ti–Mo–Al, Ti–V–Al, etc. The total number of systems of this type is 28.

10. The tenth type of phase diagrams of ternary systems is formed as a result of a combination of binary diagrams of the 3rd and 4th types, i.e., when one of the components lowers the temperature of the polymorphic transformation of titanium and causes eutectoid decomposition of the β-phase, while the second, conversely, raises the temperature of the polymorphic transformation of titanium, leading to peritectic or peritectoid reactions. Example: the Ti–Cu–Al system. The total number of such systems is 112.

The types of phase diagrams considered cover all kinds of interactions of titanium in ternary systems based on it. Experimental studies of certain ternary titanium systems[4–6] confirm the correctness of the classification set forth above.

The examples given above of the principal types of phase diagrams of ternary systems based on titanium are of great importance. They make it possible to orient researchers in formulating the problem and selecting specific ternary systems for experimental study, and also to represent in general form the character of the interaction of the elements in the selected ternary system. These types of phase diagrams make it possible to set in advance the goal of obtaining specific compositions of ternary titanium alloys with one structure or another.

In accordance with the specified composition and structure, one can count on

SovietRxiv

obtaining definite physicochemical and mechanical properties of alloys based on ternary systems, i.e., solve the problem of obtaining ternary titanium alloys with predetermined properties.

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

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