STRUCTURE AND PHASE COMPOSITION OF THE Ti–Cu DIFFUSION ZONE

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The structure, composition, and kinetics of phase formation in the Ti—Cu system are investigated by metallographic and x-ray microanalytic methods. The diffusion zone of the model system consists of layers of solid solutions and intermetallic compounds, which have different thicknesses and interface structures.

Previously published phase diagrams of the Ti–Cu system have a number of significant differences [1-7]. The main differences are in the identification of intermetallic compounds with a predominant copper concentration. The intermetallic compound that is in equilibrium with a copper-based solid solution on the phase diagram is designated Ti_2Cu_7 in some publications and $TiCu_4$ in others. A feature that equilibrium diagrams have in common is a eutectic, which incorporates the most copper-rich compound. Different opinions were held, however, about the second eutectic component. The formula $TiCu_2$ is given for the intermetallic compound in [3, 4] and Ti_2Cu_3 in [2, 5, 6]. Bennet et al. [3] and Schaft et al. [4] confirmed the presence of both phases, $TiCu_2$ and Ti_2Cu_3, while $TiCu_2$ is not present on the diagram in [6]. Likely the most up-to-date form of the diagram is given in [8], but the author does express doubts as to the accuracy of the experimental data for alloys with 30 to 75 at.% Cu. The eutectic reaction L $\Leftrightarrow$ $TiCu_2$ + β-$TiCu_4$ (875 $\pm$ 10°C) and a cascade of peritectic reactions with the participation of the compounds Ti_3Cu_4, Ti_2Cu_3, $TiCu_2$, and $TiCu_4$, which come from TiCu. Moreover, eutectoid and peritectoid transformations occur here.

It is of interest to study the structure-forming processes that occur alloys of this system during sintering in regard to practical application and the development of a production technology. The results of such studies may also be useful for working out the scientific foundations of solid-phase interactions.

A specimen was prepared by pressing a copper cylinder (99.99% pure) of diameter 5 mm and thickness 3 mm into a hole in a previously sintered titanium disk (99.96% pure) 3 mm thick. The specimen was then vacuum annealed at 850 $\pm$ 10°C for 2 h and its surface was then polished and etched. The microstructure of the diffusion zone was studied by optical and electron scanning microscopy as well as with a microanalyzer.

The diffusion zone, a general view of which is shown in Fig. 1a-e, has width of the order of 1.5 mm. It has been arbitrarily divided into four parts. As shown by local x-ray spectrum microanalysis, phase A (a narrow band with a continuous boundary with copper) contains 21.769 at. % Ti and 78.2371 at.% Cu, which corresponds to the intermetallic compound $TiCu_4$. Beyond that intermetallic layer, on the copper side, 50 μm from the boundary is a region of copper-based solid solution with a titanium that decreases from 7% to 1%. On the other side layer A borders on an extensive multiphase region, which has a structure that changes smoothly in nature in the direction toward the titanium. Closer to the boundary with $TiCu_4$ that region is represented by the bright matrix C, which is penetrated by dark narrow interlayers B with a directed orientation and a two-phase structure (Fig. 1f, g). The composition of phase C is 30.805 at.% Ti and 69.9195 at.% Cu, which is close to the composition of the intermetallic compound $TiCu_2$.

Closer to the titanium the area occupied by the two-phase colonies B increases so that finally they become the matrix phase, in which bright crystals D grow from the titanium side; those crystals are branches of the layer of the next intermetallic compound Ti_2Cu_3 (37.9853 at.% Ti and 62.0417 at.% Cu). It is seen from Fig. 1h that the branches of such a compound are genetically related to the finely differentiated two-phase structure, the exterior view of which is characteristic of eutectoids. In all probability, it is a product of the eutectoid reaction $TiCu_2$ $\Leftrightarrow$ Ti_2Cu_3 + β-$TiCu_4$, which occurs at 870 $\pm$ 10°C. In turn, β-$TiCu_4$ can transform into the eutectoid Ti_2Cu_3 + α-$TiCu_4$ at roughly 400°C [8].

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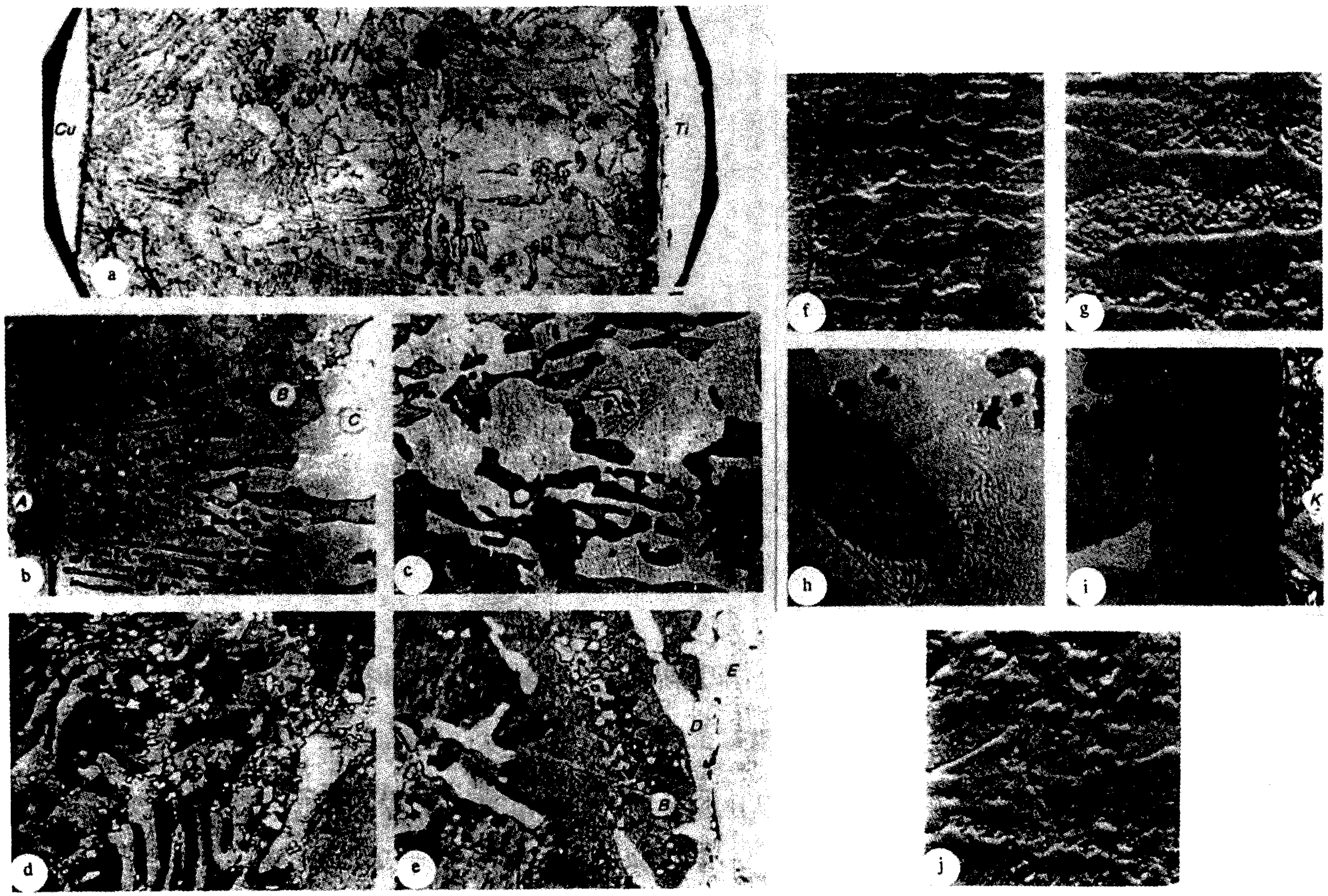

Fig. 1. Diffusion zone between titanium and copper: a-e) general view; f-g) eutectic colonies in the Ti_2Cu_3 matrix; h) bond of the eutectic $TiCu_2-Ti_2Cu_3$ with the base crystal Ti_2Cu_3; i) bond of the eutectic $Ti_2Cu-TiCu$ with Ti_2Cu crystals; j) structure with polyhedral TiCu crystals. Magnification: 200 (a), 500 (b-e), 600 (f), and 1140 (g-j).

On the basis of the metallographic analysis we can conclude that the intermetallic compound Ti_2Cu_3 plays the leading role in the cooperative crystallization. Unfortunately, the exact chemical composition of the eutectoid component could not be determined experimentally for technical reasons. The eutectoid parts near the Ti_2Cu_3 layer contain more titanium than do those closer to the boundary with the $TiCu_4$ layer. The chemical composition of the layer of phase E, which borders on the layer of the intermetallic compound Ti_2Cu_3 of approximately the same thickness, corresponds to the formula TiCu (50.6598 at.% Ti, 49.3402 at.% Cu). Beyond the TiCu layer in the diffusion zone we detected a layer of one more intermetallic compound, identified as Ti_2Cu (67.4349 at.% Ti, 32.5651 at.% Cu). In the direction of the titanium this layer, the thinnest, has bright branches K, which, as it were, grow into a matrix with a finely differentiated two-phase structure, judging by Fig. 1. On the basis of the Ti–Cu phase diagram [8] this structural formation evidently can be attributed to the product if the eutectoid reaction β-Ti $\Leftrightarrow$ α-Ti + Ti_2Cu (790 $\pm$ 10°C). Beyond that region we found a thin layer of a solution of copper in titanium (0.8-2.5 at.%). We were unable to detect the intermetallic compound Ti_3Cu_4 in the phase diagram.

It is characteristic of the system studied here that bright crystals with a regular shape, most often faceted (Fig. 1j), which are uniformly distributed among all the structural components, exist in the diffusion zone from the Ti_2Cu_3 layer to the $TiCu_4$ layer. These crystals have been determined to represent the intermetallic compound TiCu. In view of this we can note that alloys of the Ti–Cu system are aging systems and under the conditions of supersaturation of the phases they may additionally precipitate crystals of intermetallic compounds.

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