DECOMPOSITION OF A METASTABLE SOLID SOLUTION IN URANIUM-MOLYBDENUM ALLOY

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The process leading to the decomposition of a metastable solid solution ($\gamma$ phase) in uranium alloys with 13.6 and 20 at.% molybdenum under isothermal holding conditions at the temperature of the phase regions $\alpha + \gamma$ and $\alpha + \gamma$ of the phase diagram was examined. The process was studied by the methods of metallography and x-ray crystallographic analysis.

The changes in the microstructure and phase composition of the alloys as a function of the temperature and holding time were indicated. The decomposition process was represented in the form of C-shaped diagrams of the isothermal transformation of the $\gamma$ phase, which characterize the structural changes occurring in the alloy in the direction of the equilibrium state. It was found that the process occurs in stages. 6 figures. 7 references.

Numerous publications in the domestic and foreign literature which are devoted to the decomposition of supersaturated solid solutions during the aging metallic alloys attest to the fact that decomposition processes are mainly of three types — continuous, intermittent, and low-temperature — in spite of characteristic features that are due to the nature and character of the interacting metals, the diffusion characteristics of the alloy components, the temperature-time parameters of the experiments, and so on [1].

Alloys of uranium with transition metals, specifically, molybdenum, which tend to form metastable phases as a result of quenching of a $\gamma$-hard solution, in this sense are not exceptions [2, 3]. According to modern ideas about metastable states, as the molybdenum content in a uranium-based alloy increases up to the atomic fraction 32–33% under the conditions of quenching from the temperature of the region of the $\gamma$ hard solution ($\gamma$ phase with bcc structure), a concentration sequence of formation of metastable phases $\alpha'_p$ - $\beta$ - $\gamma$ - $\gamma$ is obtained [2–6].

In the present work the characteristic features of the structure of the $\gamma$ phase formed in the range of atomic fraction of molybdenum in uranium ~12.4–23.6%, i.e., in a specific alloy with molybdenum atomic fractions of 13.6 and 20%, are studied. As shown in [4], the $\gamma$ phase possesses a cubic structure with 16 atoms per unit cell. Such a structure arises as a result of eight centering atoms being displaced in the direction of the three-fold axis from their ideal positions in the initial bcc cell of the $\gamma$ phase doubled along three axes. The uranium and molybdenum atoms are randomly distributed over the following positions of the $\bar{I}4_3m$ space group:

\[
\begin{align*}
2(a): & \ 000 \\
6(b): & \ 0,1/2,1/2; 1/2,0,1/2; 1/2,1/2,0 \\
8(c): & \ \frac{1}{2}, \frac{1}{2}, \frac{1}{2} \quad \frac{1}{2}, \frac{1}{2}, \frac{1}{2} \quad \frac{1}{2}, \frac{1}{2}, \frac{1}{2} \quad \frac{1}{2}, \frac{1}{2}, \frac{1}{2} \\
\end{align*}
\]

The atomic parameter $x = 0.25$ corresponds to an ideal bcc structure of the $\gamma$ phase and the value 0.24 in the structure of the $\gamma'$ phase with 12.4 at.% molybdenum corresponds to the maximum displacement of the centering atoms of the initial

*Deceased.

The atomic parameter $x$ systematically approaches 0.25 as the molybdenum content in the alloys increases, and accordingly the displacement of the centering atoms from their ideal positions decreases and the structure of the $\gamma'$ phase approaches the structure of the $\gamma$ phase. As is well known, the structure of the $\gamma$ phase is characterized by the coordination number 8, i.e., the presence of eight interatomic bonds at distance $d = 0.301$ nm. The formation of a $\gamma'$ phase is accompanied by the appearance of four short $d_1$ and $d_2$ and four longer $d_3$ and $d_4$ bonds. For an alloy with 13.6 at. % molybdenum, the shortest and longest bonds are 0.288 and 0.307 nm, respectively, the difference being 0.019 nm. A decrease in the distance between long and short bonds in more highly doped alloys and the approach of their structure to an ideal bcc lattice makes the metastable state of the alloy with 20 at.% molybdenum more stable than that of the alloy with 13.6 at.% molybdenum. The dimensions of the pseudocell are 0.3437 and 0.3418 nm, respectively (as noted above, the true cell is twice as large).

**Uranium Alloy with 20 at.% Molybdenum.** On account of the high stability of the metastable state, the $\gamma'$ phase of this alloy is fixed at room temperature under the conditions of slow cooling from the $\gamma$ region (cooling rate $\approx 0.1^\circ$C/sec). The microstructure of the $\gamma'$ phase is a polyhedral grain of a solid solution with pure fine boundaries (Fig. 1).

The C-shaped diagram of the isothermal process leading to the decomposition of the metastable $\gamma'$ phase of the alloy in the temperature range 400–600°C is presented in Fig. 2. In this figure the temperature 400–570°C refers to the phase region $\alpha + \gamma'$ ($U_2Mo$) of the phase diagram of uranium-molybdenum alloy above 570°C up to 600°C – up to the $\alpha + \gamma$ region [2, 3]. We note that in [7] preliminary heat treatment of samples of a uranium alloy with 9 mass% (20 at.%) molybdenum with $\gamma$-phase structure was monitored according to two C-shaped curves, constructed beforehand from measurements of the resistivity, in order to obtain the structure of the eutectoid $\alpha + \gamma'$ with grains of different size for subsequent neutron irradiation.