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CHEMISTRY

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PHASE-EQUILIBRIUM DIAGRAM OF THE CHROMIUM–OSMIUM SYSTEM

According to published data on the phase composition of chromium alloys with osmium ([1–3]), two intermetallic compounds are formed in this system: Cr_2Os, with a crystal lattice of the σ-phase type, and Cr_3Os, with a crystal lattice of the β–W type. A considerable mutual solubility of the components has been established. According to the data of work ([2]), in the temperature interval 600-1350° C the solubility of osmium in chromium is approximately 9.5 at. %, and that of chromium in osmium is 51.7 at. %. It was established that during prolonged annealing of alloys at 900° decomposition of the compound Cr_2Os occurs into two phases: Cr_3Os and a solid solution of chromium in osmium.

Table 1

No.	At. % Os	Wt. % Os	No.	At. % Os	Wt. % Os
1	0.0	0.0	13	25.0	55.0
2	0.8	4.0	14	26.0	56.0
3	2.0	8.0	15	27.5	58.0
4	5.0	16.15	16	30.0	61.0
5	8.0	24.0	17	33.3	64.5
6	9.0	26.5	18	35.0	66.5
7	10.0	28.9	19	39.0	70.0
8	12.0	33.0	20	41.0	71.7
9	15.0	29.5	21	45.0	75.0
10	20.0	47.6	22	48.0	77.2
11	22.5	51.3	23	51.0	79.2
12	24.0	53.5	24	100.0	100.0

Chromium–osmium alloys weighing 10 g were prepared in an arc furnace on a water-cooled copper hearth in an argon atmosphere. The argon was gettered by melting a titanium-zirconium alloy (60 wt. % Zr and 40 wt. % Ti). The starting charge materials used were electrolytic chromium of 99.92% purity and metallic powdered osmium of 99.96% purity. The composition of the alloys studied is given in Table 1.

The correspondence between the charge composition and the actual composition of the alloys was checked by comparing the weight of the charge with the weight of the ingots, and also by control chemical analysis.

To eliminate possible dendritic liquation, all alloys were subjected to homogenizing annealing at a temperature of 1700° for 55 hours. The alloys were then annealed at temperatures of 1580° (50 hours), 1500° (50 hours), 1300° (115 hours), 1100° (130 hours), and 950° (130 hours). Annealing at temperatures of 1300° and above was carried out in a TVV-2M furnace, and at temperatures of 1100 and 950°—in quartz ampoules in an atmosphere of purified argon.

The melting diagram (solidus and liquidus) of the system was constructed from the results of differential thermal analysis of alloys Nos. 1, 6, 9, 13, 16, 19, and 21. Figure 1A shows the heating and cooling thermogram of alloy No. 9. Melting of the sample begins at a temperature of 1890° and ends at 1900°. Crystallization of the alloy occurs in the temperature interval 1850–1800°. The thermogram of alloy No. 16 is presented in Fig. 1 . At a temperature of 1670° a transformation in the solid state occurs in the alloy; melting begins at a temperature of 1845° and ends at 1880°.

Phase analysis of the alloys after various annealings was carried out by metallographic and X-ray methods.

Fig. 1. Thermogram of an alloy containing 15 at.% Os (A) and 30 at.% Os (B)

Fig. 2. Phase-equilibrium diagram of the chromium—osmium system

Fig. 3. Effect of osmium on the microhardness and crystal-lattice parameter of chromium

The phase-equilibrium diagram of the chromium—osmium system, shown in Fig. 2, is a diagram of the eutectic type. The temperature of the eutectic reaction ($L \rightleftarrows \alpha + \beta$) is $1840 \pm 10°$. The eutectic alloy contains 33 at.% (64 wt.%) Os. The σ-phase (the compound Cr_2Os) forms after crystallization of the eutectic by the peritectoid reaction $\alpha + \beta \rightarrow \sigma$ at a temperature of $1670 \pm 15°$. Upon further cooling of the alloys, decomposition of the σ-phase is observed according to the eutectoid reaction $\sigma \rightarrow Cr_3Os + \beta$ at a temperature of $975 \pm 25°$. This temperature has been taken as the average between 950 and 1000°, since after annealing the alloys at 950° decomposition of the σ-phase is visible, whereas after annealing at 1000°, according to the data of work ([2]), decomposition of the σ-phase was not established.

The compound Cr_3Os forms by the peritectoid reaction $\alpha + \sigma \rightarrow Cr_3Os$ at $1540 \pm 40°$. This temperature has been taken as the average between 1580 and

1500°,

since the compound Cr_3Os forms in the corresponding alloys after annealing at 1500° and does not form after annealing at 1580°.

It should be noted that at 1670° the σ-phase forms and decomposes under conditions of continuous heating and cooling of the alloys. Moreover, an alloy of σ-phase composition, after quenching in oil from the two-phase region $\alpha + \beta$ (quenching temperature 1740°), consisted entirely of σ-phase. The compound Cr_3Os, however, can be obtained only by prolonged annealing of the corresponding alloys at temperatures of 1500° and below. For this reason, the cast alloy of the composition of the compound Cr_3Os is a solid solution of osmium in chromium (α-phase). This same alloy, annealed at 1700°, has the structure $\alpha + \sigma$, and after annealing at 1500° and below the compound Cr_3Os forms, although with the annealing times we used it was not possible to obtain a single-phase alloy consisting only of the Cr_3Os phase.

In the phase diagram (Fig. 2) the homogeneity range of the Cr_3Os phase is not indicated. However, displacement of the lines in the X-ray patterns of annealed alloys indicates that the Cr_3Os phase has a certain homogeneity range, the magnitude of which could not be established because of the difficulty of bringing the alloys to a fully equilibrium state.

Osmium substantially increases the hardness and the lattice parameter of chromium (Fig. 3). The hardness was measured on a PMT-3 instrument under a load of 100 g. The compound Cr_3Os has a comparatively low hardness, on the order of 600 kg/mm^2, close to the hardness of the α-phase saturated with osmium. The hardness of the σ-phase, depending on composition, varies within the limits 1800–2000 kg/mm^2. The hardness of the saturated β-phase is about 800 kg/mm^2.

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