The ternary chromium – rhenium – boron system

V. S. Telegus, Yu. B. Kuz'ma, and Ts. K. Stefanishina

The equilibrium phase diagram of the Cr–Re–B system has not been established. The aim of the present investigation was to study the phase transformations in this system.

Binary System. The literature information on the binary Cr–B and Re–B systems and also data on the crystal structures of chromium and rhenium borides were given by us in [1,2].

A fuller phase diagram of the Cr–Re system was given in [3]. The single binary compound Cr₂Re₃ (α-phase) is formed by a peritectic reaction at 2350°C; the region of homogeneity of the α-phase is 57–64 at.% Re. According to data of [4,3], the α-phase of the Cr–Re system has a tetragonal structure of the β-U type (a = 9.23, c = 4.80 Å, c/α = 0.52). At 1400°C, chromium dissolves about 38 at.% Re and rhenium about 5 at.% Cr.

Method of investigation. The samples for the investigation were prepared from powder rhenium (99.7%), chromium (99.5%), and boron (99.3%). The pressed charge was melted in an electric arc furnace in an atmosphere of purified argon. Heat treatment was carried out at 1400°C (residual pressure 10⁻³ mm Hg) for 100 h and the samples were cooled in the furnace. The composition of the samples was verified by control weighing. X-ray structural (powder method) and microstructural analyses were used for the investigation.

Phase Equilibria. As a result of the x-ray phase and microstructural analyses, an isothermal section was constructed for the phase diagram of the Cr–Re–B system at 1400°C (Fig. 1).

The compound Cr₂B (rhombic structure) dissolved up to 50 at.% Re; substitution of chromium for rhenium increases the lattice parameter and the volume of the unit cell (Fig. 2); the limiting composition of the solid solution has lattice parameters of: a = 15.651, b = 7.709, c = 4.473 Å. The solubility of rhenium in the compound CrB does not exceed 5 at.%; the lattice parameters (a = 2.992, b = 7.899, c = 2.948 Å) increase somewhat compared with those for CrB (a = 2.964, b = 7.858, c = 2.934 Å). Rhenium dissolves only slightly in the compounds Cr₂B₃, Cr₃B₄, CrB₂, and CrB₆.

With increase in boron content in the rhenium borides, the solubility of chromium decreases. Thus, Re₂B dissolves about 10 at.% Cr (lattice parameter during this decreases from a = 2.891, b = 9.311, c = 7.260 Å to a = 2.887, b = 9.306, c = 7.242 Å), Re₃B₂ up to 5 at.% Cr (decrease in lattice parameters from a = 7.505, c = 4.882 Å to a = 7.489, c = 4.860 Å), and ReB₂ practically does not dissolve Cr (lattice parameter varies in the limits possible for the region of homogeneity of ReB₂: a = 2.897-2.889, c = 7.475-7.468 Å).

We established in the Cr–Re–B system the existence of a ternary compound, the region of homogeneity of which is on the isoconcentration line 50 at.% B with 15–20 at.% Re and includes the composition Cr₃Re₂B₅. This ternary compound is in equilibrium with the solid solutions based on Cr₂B, CrB, and ReB₂. The characteristic photomicrographs of alloys of the Cr–Re–B system are given in Fig. 3, and confirm the phase equilibria given in Fig. 1.

Crystal Structures. The x-ray pattern of the ternary compound Cr₃Re₂B₅ found by us is indexed with rhombic symmetry (Table 1); the lattice parameters have the values a = 5.698 ± 0.005, b = 2.959 ± 0.003, c = 4.261 ± 0.003 Å (35 at.% Cr, 15 at.% Re, 50 at.% B) or a = 5.749 ± 0.005, b = 2.973 ± 0.003, c = 4.297 ± 0.003 Å (30 at.% Cr, 20 at.% Re, 50 at.% B). The presence on the x-ray pattern of the lines 0kl with k + l = 2n and hkh0 with h = 2n indicates the space group Pnma − D₁₆h. The values of the lattice parameters, their symmetry and composition indicate the possible type of the structure of Cr₃Re₂B₅ to be the FeB type. For proof of this proposal, we calculated the intensities of the interference assuming the following positions of the atoms in the space group Pnma − D₁₆h: (2.4Cr ± 1.6Re) statistically in 4(0) x/2/z with x = 0.180, z = 0.125; 4B in 4(0) with x = 0.036, z = 0.610. As can be seen from Table 1, the calculated intensities agree well with the observed and this confirms the present in the compound Cr₃Re₂B₅ of the crystal structure FeB.
Fig. 1. Isothermal section of the phase diagram of the system at 1400°C: 1) single phased; 2) two phased, 3) three phased samples.

Fig. 2. Change in lattice parameter of Cr₂B during dissolution of rhenium.

Fig. 3. Photomicrographs of alloys of the Cr-Re-B system (composition indicated in at.% in the following sequence: Cr, Re, B), x 450: a) 70.0, 15.0, 15.0; α + (Cr, Re)₂B; b) 60.0, 15.0, 25.0; β + (Re, Cr)₃B + (Cr, Re)₂B; c) 40.0, 10.0, 50.0; (Cr, Re)B + Cr₂Re₂B₃; d) 30.0, 20.0, 50.0; Cr₂Re₂B₃; e) 20.0, 30.0, 50.0; Cr₂Re₂B₂ + ReB₂ + (Cr, Re)₂B; f) 12.0, 12.0, 76.0; ReB₂ + (Cr, Re)B₃ + CrB₃.