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Rhenium solid solution in the Cr–Re–C ternary system at solidus temperature

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Abstract

The Cr–Re–C system was investigated by metallography, X-ray diffraction, microprobe, differential thermal analyses and Pirani–Alterthum techniques and the solidus surface was constructed. The combined maximum solubility of chromium and carbon in rhenium at solidus temperature (1700°C) was found to be 53 and 36 at.%, respectively. The lattice parameters at this composition, $(Cr_{0.82}Re_{0.18})_2C$ carbide, are $a = 0.2833(1)$ and $c = 0.4443(6)$ nm. © 1997 Elsevier Science S.A.

Keywords: Cr–Re–C system; Lattice parameters; Solubility

1. Introduction

The fact that rhenium improves the mechanical properties of multicomponent chromium alloys (containing rhenium and carbon together with other elements) focuses our interest on the Re–Cr–C ternary system. The phase diagram also supplements those of the systems Re–M–C (M = W, Mo, V, Ti) and Cr–M–C (M = Sc, Ti, Zr, Hf, Nb, Ta, Mo, W, Ni) investigated by us previously [1–3].

In an earlier investigation of the Cr–Re–C system [4] the isothermal section at 1300°C was constructed. The authors [4] claimed that the combined chromium and carbon solubility does not exceed the individual solubilities.

2. Experimental

Forty-four alloys were prepared in an arc furnace with a non-consumable tungsten electrode on a water-cooled copper boat in a gettered argon atmosphere. The compositions of the alloys studied are presented in Fig. 1. The starting materials were: electrolytic chromium refined by annealing in hydrogen (~ 99.9% Cr), rhenium powder (≥ 99.8) and atomic graphite. A few well-tested master alloys were used. The total weight losses of alloys during melting were < 0.5% (except for Re-rich alloys) and were generally attributed to the evaporation of chromium and carbon in the proportion 2:1 (from chemical analysis). The alloys were investigated by metallography, X-ray diffraction and microprobe analyses (JEOL "Superprobe 733"). Phase transformation temperatures were determined by differential thermal analysis (DTA) and the Pirani–Alterthum method [5] (solidus temperature). The samples were annealed for 30 min at about 30–50°C below solidus temperatures and quenched. X-ray diffraction was performed on the cast and annealed alloys employing the Debye–Scherer method with a 57.3 mm diameter camera and Cu or Cr Kα radiation. Calculations of lattice parameters were carried out by a modified Kogan–Hëss method.

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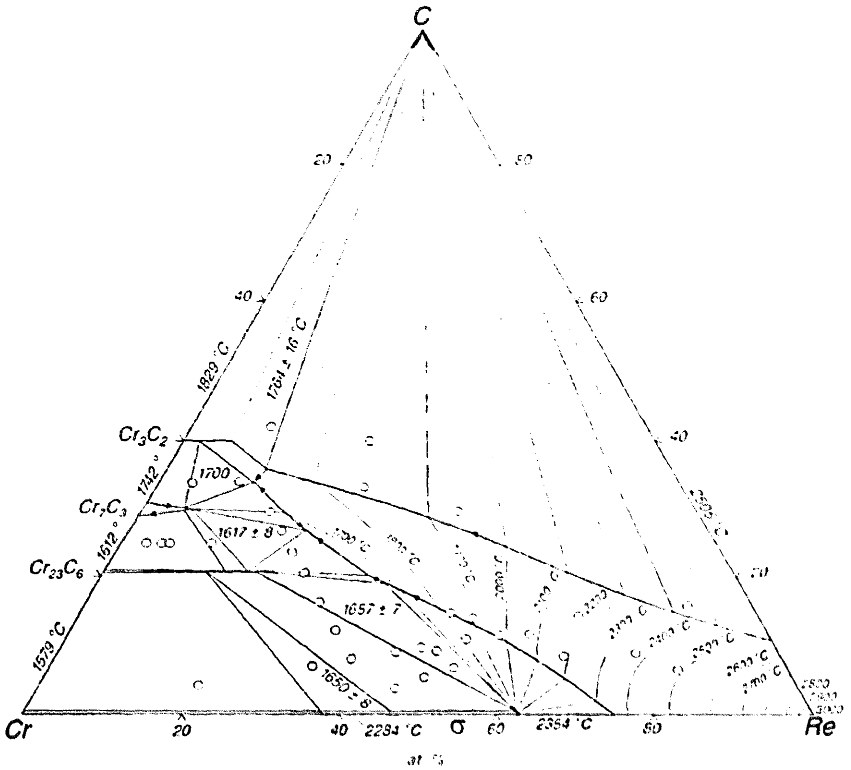

Fig. 1. The solidus surface p. ɔjection of the Cr–Re–C system.

3. Results

The phase diagrams of the binary systems were used according to Massalski's handbook [6]. For the temperatures of invariant equilibria in the Cr–C system the data of Ref. [7] were preferred. It should be noted that our determination of the homogeneity region for the σ-phase in the ternary system is not in agreement with data for the Cr–Re binary.

No ternary compounds were found. Maximal rhe-

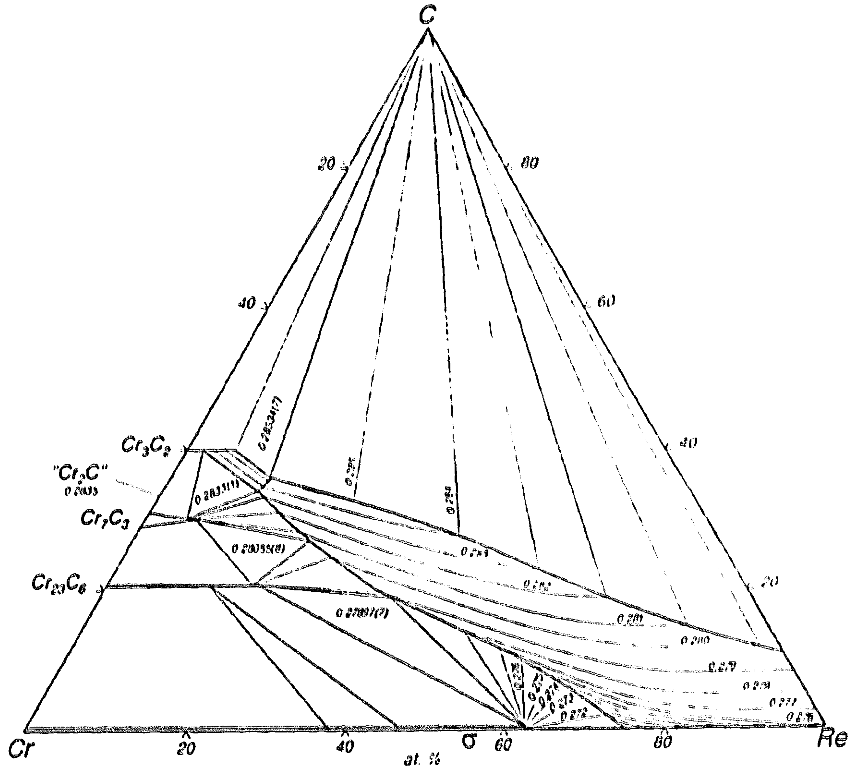

Fig. 2. The *a*-isoparameter lines of the rhenium phase in the Cr–Re–C system.

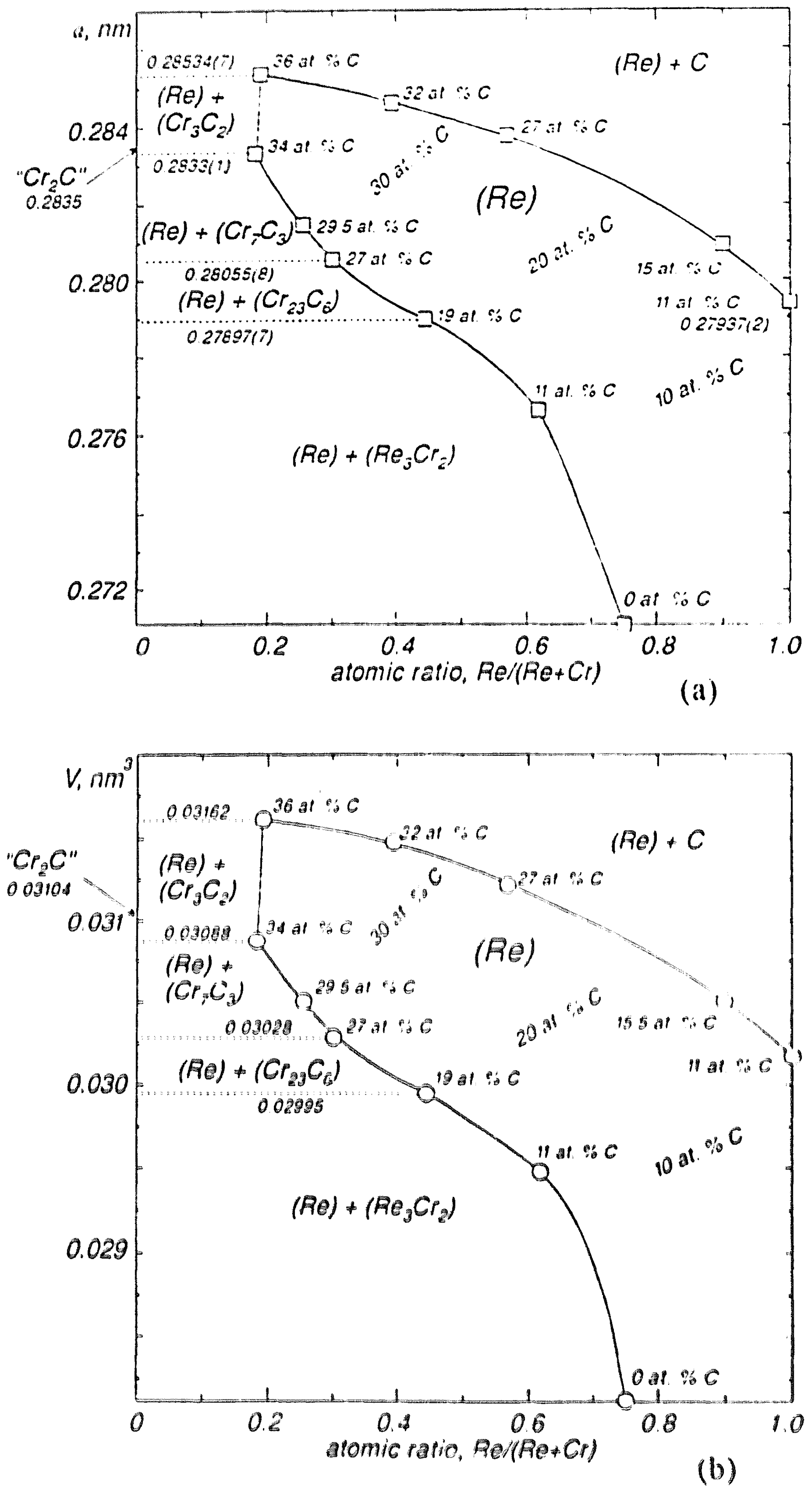

Fig. 3. The a-lattice parameters (a) and cell volume (b) of the rhenium phase vs. metal atomic ratio.

nium solubilities were about 19, 6, and 6 at.% in $Cr_{23}C_6$, Cr_7C_3 and Cr_3C_2, respectively. The solubility of rhenium increases the lattice parameters of these carbides in accordance with the atomic radii of chromium and rhenium.

The essential singularity of the Cr–Re–C system is the huge joint chromium and carbon solubility in rhenium at solidus temperature, amounting to 53 and 36 at.%, respectively, at 1700°C. It is so high that this composition may be considered as a ternary compound, $(Cr_{0.82}Re_{0.18})_2C$, forming a continuous solid solution with rhenium. The lattice parameters of $(Cr_{0.82}Re_{0.18})_2C$ are $a = 0.2833(1)$ and $c = 0.4443(6)$ nm, larger than those for pure rhenium, although the chromium atomic radius is smaller than that for rhenium. Figs. 2 and 3 show the combined influence of both solved components on the lattice parameters of the rhenium phase. The rhenium phase forms equilibria with all phases, except Cr, and hence it specifies the constitution of the phase diagram (Fig. 1).

4. Discussion

The huge joint solubility of chromium and carbon in rhenium on the solidus surface is surprising when compared with data reported previously for 1300°C [4]. However, our result is feasible in view with the Re–Mo(W)–C and Cr–Mo(W)–C systems investigated [1,7,8] (Fig. 4). The metallic sublattices of Mo_2C and W_2C are isostructural to the hcp rhenium lattice and the lattice parameters of these phases are similar. This is why hcp continuous solid solutions are formed in Re–Mo(W)–C systems. On the other hand, in Cr–Mo(W)–C systems the Mo_2C and W_2C phases solve so much chromium that the solid solution almost reaches the Cr–C side. Therefore, the chromium-saturated compositions, $(Cr_{0.9}Mo_{0.1})_2C$ and $(Cr_{0.9}W_{0.1})_2C$, may be treated as stabilized hcp carbide "Cr_2C". Indeed, the lattice parameters of "Cr_2C", $a = 0.2835$ and $c = 0.446$ nm, obtained by extrapolation of literature data [9], are similar to our data for $(Cr_{0.82}Re_{0.18})_2C$.

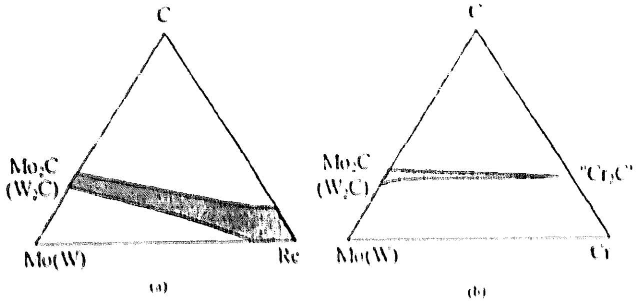

Fig. 4. Hcp phases on the solidus surface in the systems (a) Re–Mo(W)–C [1,2] and (b) Cr–Mo(W)–C [7,8].

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