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The Cr-Ni-Re (Chromium-Nickel-Rhenium) System

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Introduction

Very little work has been done in the Cr-Ni-Re system. Only one isothermal section has been established.

Binary Systems

The Cr-Ni system [Massalski2] (Fig. 1) is a simple eutectic system, the eutectic reaction L ↔ γ + α occurs at 1345 °C. The γ and α phases represent the two terminal solid solutions, face centered cubic (fcc) (Ni) and body centered cubic (bcc) (Cr), respectively. At the $CrNi_2$ composition an ordering reaction occurs at ~590 °C in the fcc γ solid solution.

The Cr-Re system [Massalski2] (Fig. 2) has one intermediate phase σ which forms through a peritectic reaction L + ε ↔ σ at 2354 °C, where ε is the terminal solid solution of close packed hexagonal (cph) (Re). On addition of Re to Cr the bcc α phase gets stabilized to higher temperatures and a peritectic reaction L + σ ↔ α occurs at 2284 °C.

The Ni-Re system [Massalski2] (Fig. 3) is a simple peritectic system, the peritectic reaction L + ε ↔ γ occurs at 1620 °C.

Binary and Ternary Phases

In the three binary systems Cr-Ni, Cr-Re, and Ni-Re, only one binary intermediate phase forms in the Cr-Re system. No ternary intermediate phase has been reported in the Cr-Ni-Re system. The phases and their structure data are given in Table 1.

Ternary System

The Cr-Ni-Re ternary system has been studied by [1998Sly] using diffusion couple techniques and arc melted solid alloys. Electrolytic Cr and Ni and vacuum melted Re were used in this study of Cr-Ni-Re ternary system. Diffusion couples were prepared using Cr-Ni alloys/Ni-Re

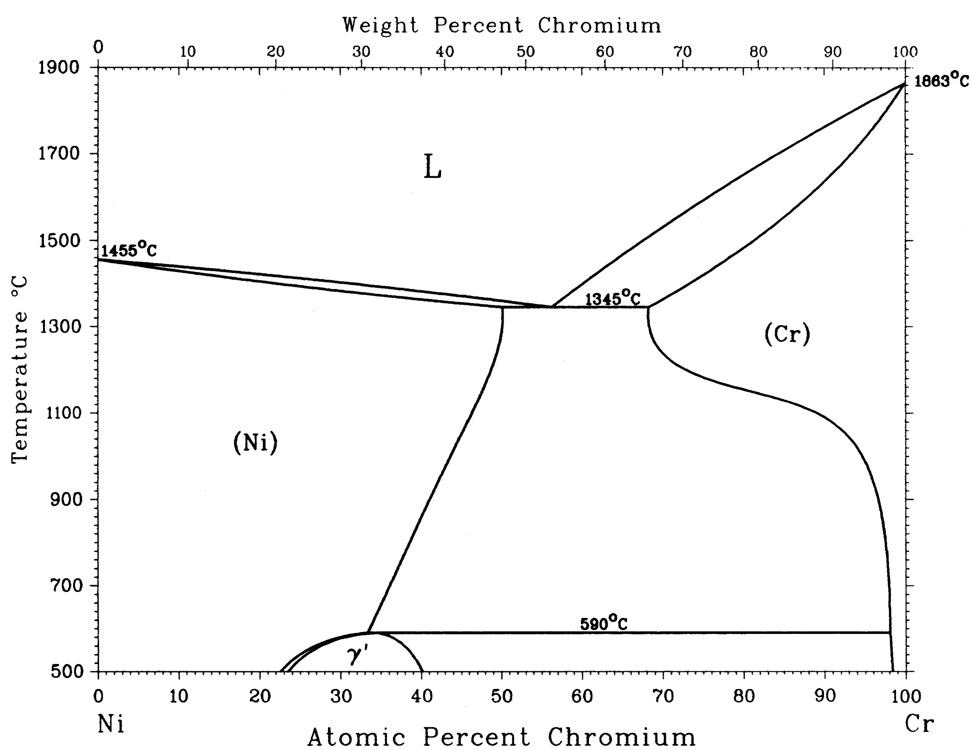

Fig. 1 Cr-Ni binary phase diagram

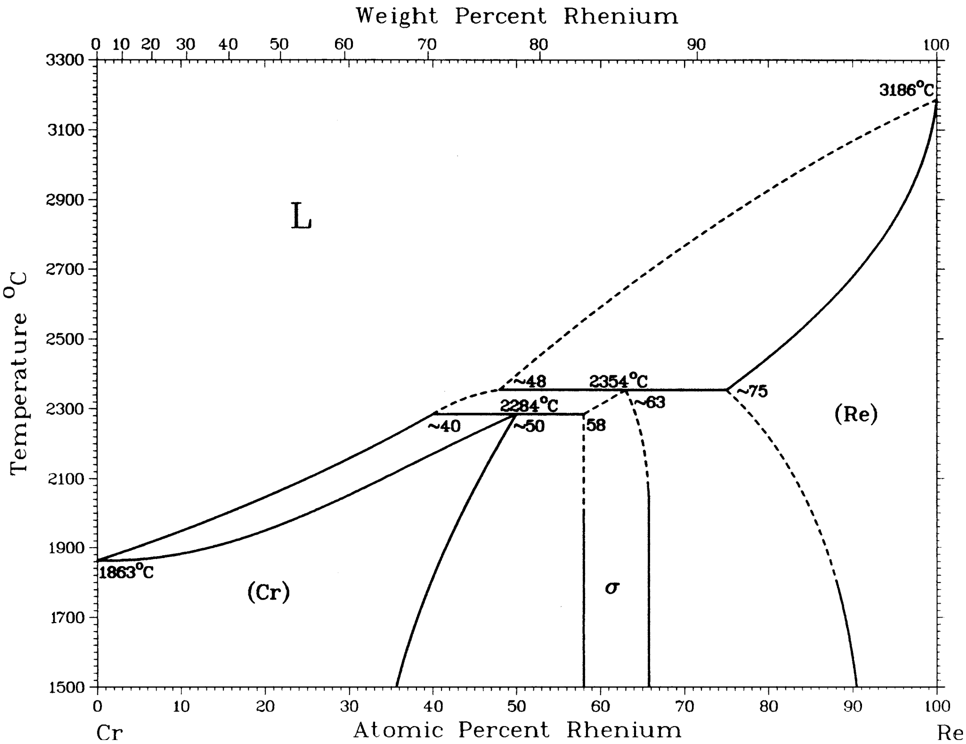

Fig. 2 Cr-Re binary phase diagram [Massalski2]

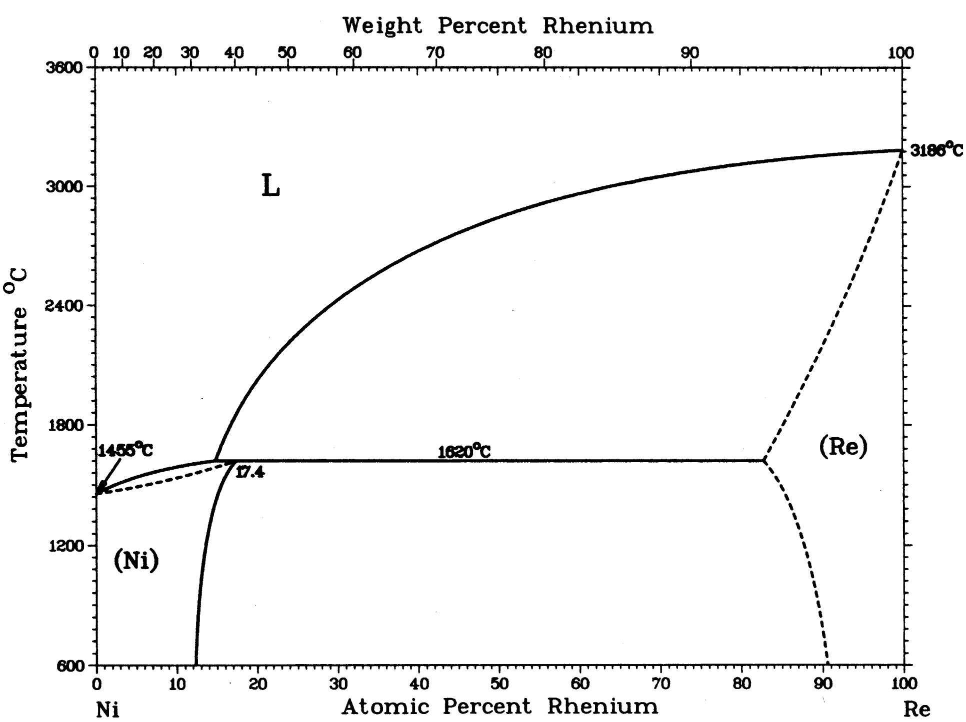

Fig. 3 Ni-Re binary phase diagram

alloys, and sandwiched couples Cr/Ni/Re were prepared using a 50 µm thick Ni layer. The diffusion couples were prepared by vacuum welding for 20 min at 1175 °C under a pressure of 34 MPa. The sandwiched couples were diffusion annealed at 1152 °C for 4 to 64 h. The alloy diffusion couples were diffusion annealed at 1152 °C for 50 and 100 h.

The arc melted alloys were sealed in silica capsules under argon atmosphere and annealed at 1152 °C for 500 h. Analysis of the diffusion zones of the diffusion couple was done by scanning electron microscopy (SEM) and electron probe microanalysis (EPMA). The phase analysis of the solid alloys was done by SEM, EPMA, and x-ray diffraction.

The diffusion couples prepared with solid alloys are $Cr_{54}Ni_{46}/Ni_{50}Re_{50}$, and $Cr_{40}Ni_{60}/Ni_{40}Re_{60}$. The former alloy couple involved two phase alloys having (α + γ) and (ε + γ) structures, respectively. The latter alloy couple involved a single phase alloy with γ phase against a two phase alloy with (γ + ε) structure. After 50 and 100 h annealing the $Cr_{54}Ni_{46}/Ni_{50}Re_5$ couple showed the sequence of phases (α + γ)/(σ + γ)/(γ + ε) across the diffusion zone. The $Cr_{40}Ni_{60}/Ni_{40}Re_{60}$ couple after 100 h annealing showed γ/(σ + γ)/(γ + ε) across the diffusion zone. The sandwiched diffusion couple after 36 h annealing produced stable structure α/σ/ε across the diffusion zone.

Table 1 Phases of the binary system Cr-Ni, Cr-Re, and Ni-Re and their structure data

Phase designation	Composition	Pearson's symbol	Space group	Type
α	(Cr)	*cI*2	$Im\bar{3}m$	W
γ	(Ni)	*cF*4	$Fm\bar{3}m$	Cu
ε	(Re)	*hp*2	$P6_3/mmc$	Mg
γ′	$CrNi_2$	*op*6	*Immm*	$MoPt_2$
σ	Cr_2Re_3	*tp*30	$p4_2/min$	σ(CrFe)

Eight arc melted solid alloys were prepared with various Cr and Re contents. The alloys $Cr_{63}Ni_{28}Re_9$ and $Cr_{19}Ni_{38}Re_{43}$ were found to have three phases, the $Cr_{42}Ni_{18}Re_{40}$, $Cr_{35}Ni_{19}Re_{46}$, and $Cr_{50}Ni_{13}Re_{37}$ alloys were found to be single phases σ and the $Cr_{47}Ni_{39}Re_{19}$, $Cr_{32}Ni_{45}Re_{23}$, and $Cr_{41}Ni_{34}Re_{25}$ alloys were found to be two-phase. The two three-phase regions were identified as the α + σ + γ and γ + σ + ε regions. The isothermal section of 1152 °C determined through these studies is given in Fig. 4. The σ phase was found in equilibrium with the three terminal solid solutions α, γ, and ε. The phase boundaries of the binary phases given in the established isothermal section at 1152 °C, however, do not agree well with the accepted binary data. The probable expected phase boundaries of the α, γ, ε, and α phases at 1152 °C are indicated by dashed lines in Fig. 4. The phase boundaries of the α, γ, ε, and σ phases should be redetermined.

The phase equilibria of the Cr-Ni-Re established by [1998Sly] shows a simple isothermal section with only two three-phase equilibrium triangles and shows the σ phase in equilibrium with the terminal solid solutions α, γ, and ε. The three binaries Cr-Ni, Cr-Re, and Ni-Re also show simple phase equilibrium, an eutectic reaction (e) in the Cr-Ni system, two peritectic reactions (P_1 and P_2) in the Cr-Re system, and a peritectic reaction (P_3) in the Ni-Re system. This information can be used to work out a probable

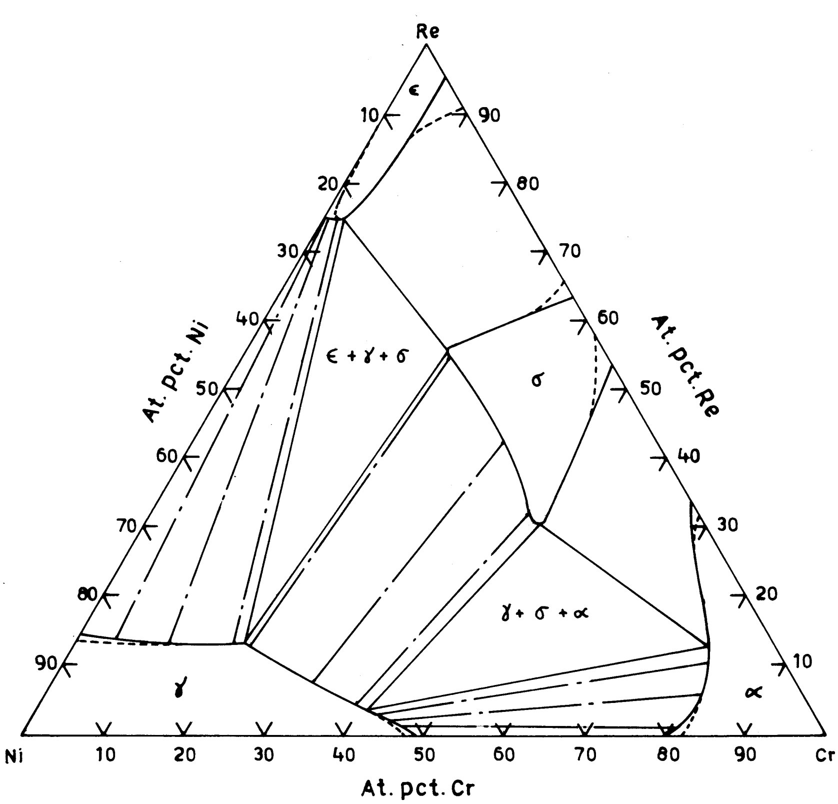

Fig. 4 An isothermal section of the Cr-Ni-Re system at 1152 °C [1998Sly]

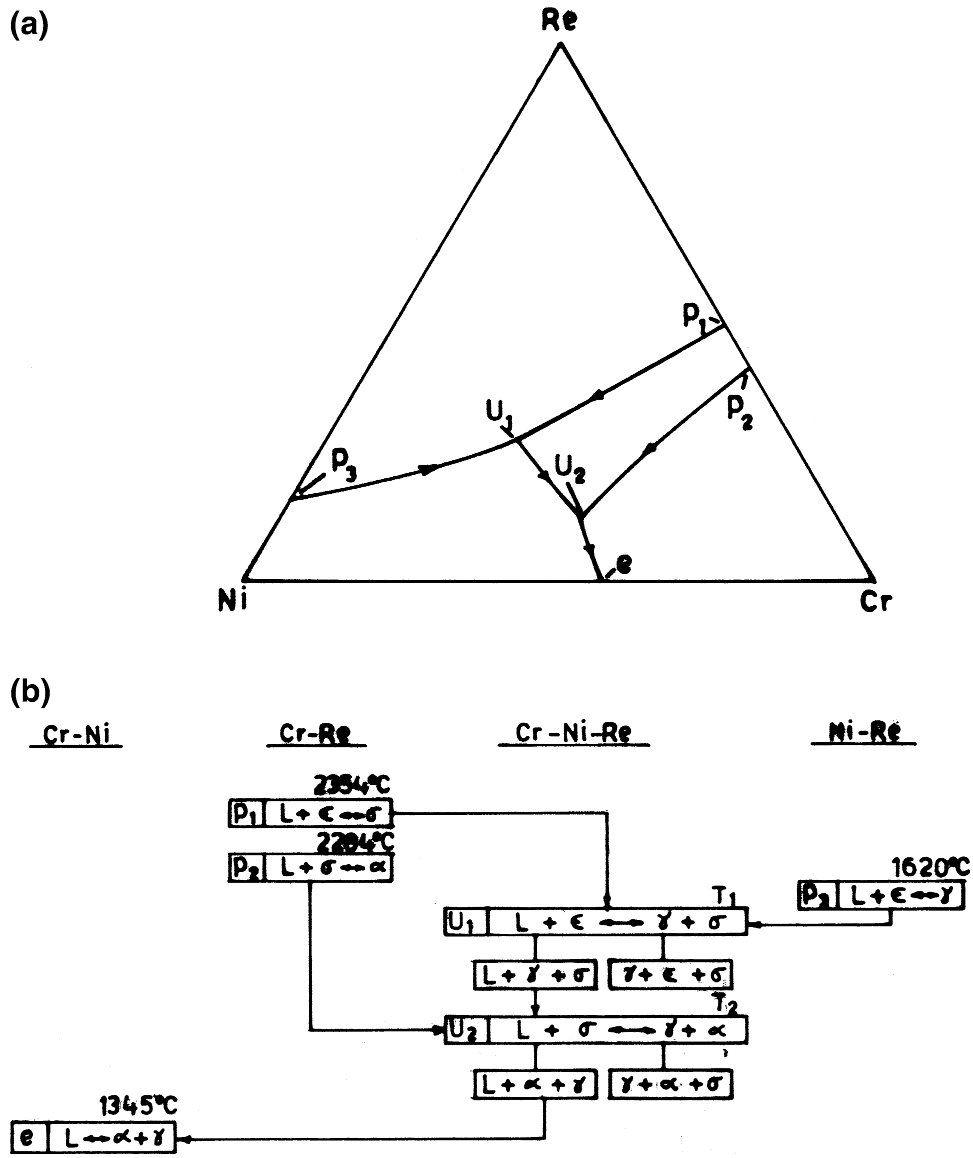

Fig. 5 (a) A probable liquidus projection (schematic) for the Cr-Ni-Re system. (b) Reaction scheme for the Cr-Ni-Re system corresponding to the liquidus projection of Fig. 2(a)

liquidus projection for the Cr-Ni-Re system. The probable liquidus projection for the Cr-Ni-Re system is given in Fig. 2(a), which shows a U type four-phase equilibrium U_1 due to liquid compositions cooling through the peritectic reaction P_1 from the Cr-Re system and peritectic reaction P_3 from the Ni-Re system to give the 3 phase region $\gamma + \varepsilon + \sigma$. The liquid composition from the U_1 reaction then reacts with liquid composition cooling through the peritectic reaction P_2 of the Cr-Re system to give the four phase reaction U_2, which gives the three phase region $\alpha + \gamma + \sigma$. The last liquid solidifies at the Cr-Ni binary eutectic point e.

The reaction scheme for the liquidus projection is given in Fig. 5(b).

References

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