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The Cr-Ni-Hf (Chromium-Nickel-Hafnium) System

K.P. Gupta, The Indian Institute of Metals, Calcutta

Introduction

The Cr-Ni-Hf system was reviewed by [2001Gup]. For development of high temperature resistant brazing alloys, the Cr-Ni-Hf system was studied at the Ni-corner. The results are reported here.

In order to discuss the results it is necessary to recapitulate the binary systems. The Cr-Hf system [Massalski2] (Fig. 1) has only one intermediate phase Cr_2Hf which exists in two polymorphic forms in high temperature Cr_2Hf (Y) phase and a low temperature Cr_2Hf (Y_1) phase. The Y phase melts congruently at 1825 °C and the polymorphic transformation temperature for the Cr_2Hf phase is 1335 °C. Two eutectics, $L \leftrightarrow \alpha + Y$ and $L \leftrightarrow Y + \alpha_1$, occur at 1665 and 1500 °C, respectively. The α and α_1 phases are the two body centered cubic (bcc) terminal solid solutions (Cr) and (βHf), respectively. A eutectoid reaction $\alpha_1 \leftrightarrow Y + \omega$ occurs at 1370 °C; ω is the close packed hexagonal (cph) terminal solid solution (αHf). The Cr-Ni system [1991Nas] (Fig. 2) is a simple eutectic system. The eutectic reaction $L \leftrightarrow \gamma + \alpha$ occurs at 1345 °C, where γ is the face centered cubic (fcc) terminal solid solution (Ni). The γ phase extends to ~50 at.% Cr and the bcc α phase extends to ~32 at.% Ni. An ordered $CrNi_2$ phase forms from the γ phase at T < 600 °C. The Hf-Ni system [1991Nas] (Fig. 3) has nine intermediate phases: $HfNi_5$ (ε), Hf_2Ni_7 (π), high temperature $HfNi_3$ (λ_1) and a low temperature $HfNi_3$ (λ), Hf_8Ni_{21} (θ), Hf_3Ni_7 (ψ), Hf_7Ni_{10} (β), Hf_9Ni_{11} (ν), HfNi (ϕ_1) phase at high temperature and HfNi (ϕ) at low temperature, and Hf_2Ni (ξ). The polymorphic transformation temperatures for the $HfNi_3$ and HfNi phases are ~1200 and 1175 °C, respectively. The π and ϕ_1 phases melt congruently at 1460 and 1530 °C, respectively. All other phases form through peritectic reactions: $L + \pi \leftrightarrow \varepsilon$ at 1240 °C, $L + \pi \leftrightarrow \lambda_1$ at 1340 °C, $L + \lambda_1 \leftrightarrow \theta$ at 1300 °C, $L + \theta \leftrightarrow \psi$ at 1350 °C, $L + \phi_1 \leftrightarrow \nu$ at 1340 °C, $L + \nu \leftrightarrow \beta$ at 1290 °C, and $L + \phi_1 \leftrightarrow \xi$ at 1200 °C. Three eutectic reactions $L \leftrightarrow \gamma + \varepsilon$, $L \leftrightarrow \psi + \beta$, and $L \leftrightarrow \xi + \omega$ occur at 1190, 1190, and 1150 °C, respectively. The θ and ψ phases exist at high temperature and transforms through eutectoid reactions $\theta \leftrightarrow \lambda + \psi$ at 1177 °C and $\psi \leftrightarrow \lambda + \beta$ at 1020 °C. The binary phases and their structure data are given in the review by [2001Gup]. No ternary phase exists in the Cr-Hf-Ni system.

The Cr-Hf-Ni system has been reinvestigated at the Ni-Corner of the Cr-Hf-Ni system by [1999Kho]. Twenty two alloys were prepared using 99.98 mass% Cr, 99.9 mass% Hf, and 99.95 mass% Ni. The alloys were arc melted

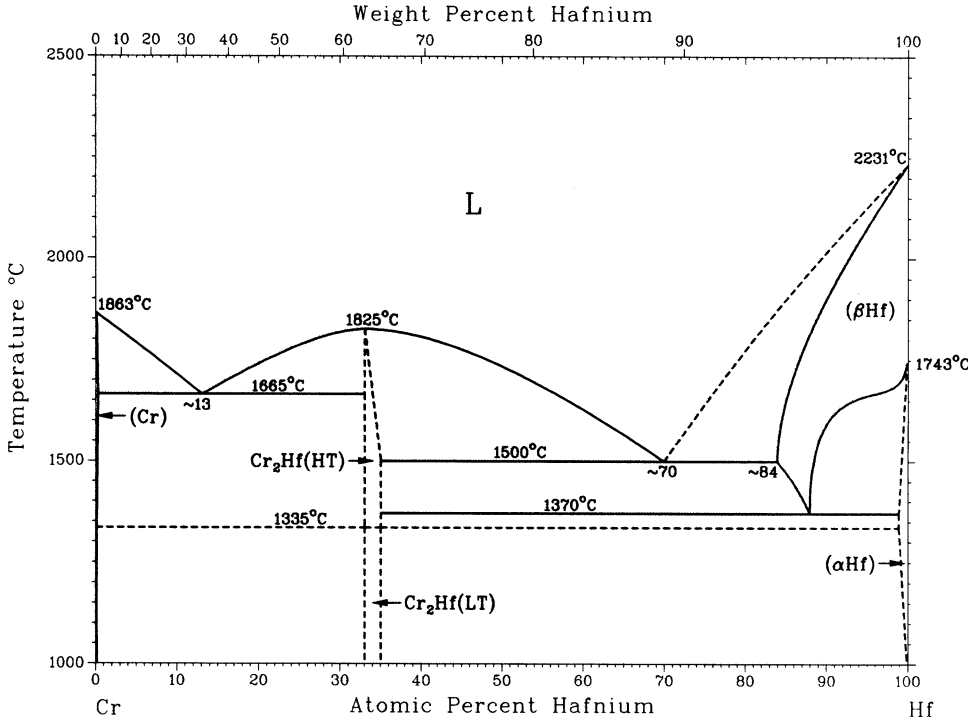

Fig. 1 The Cr-Hf system [Massalski2]

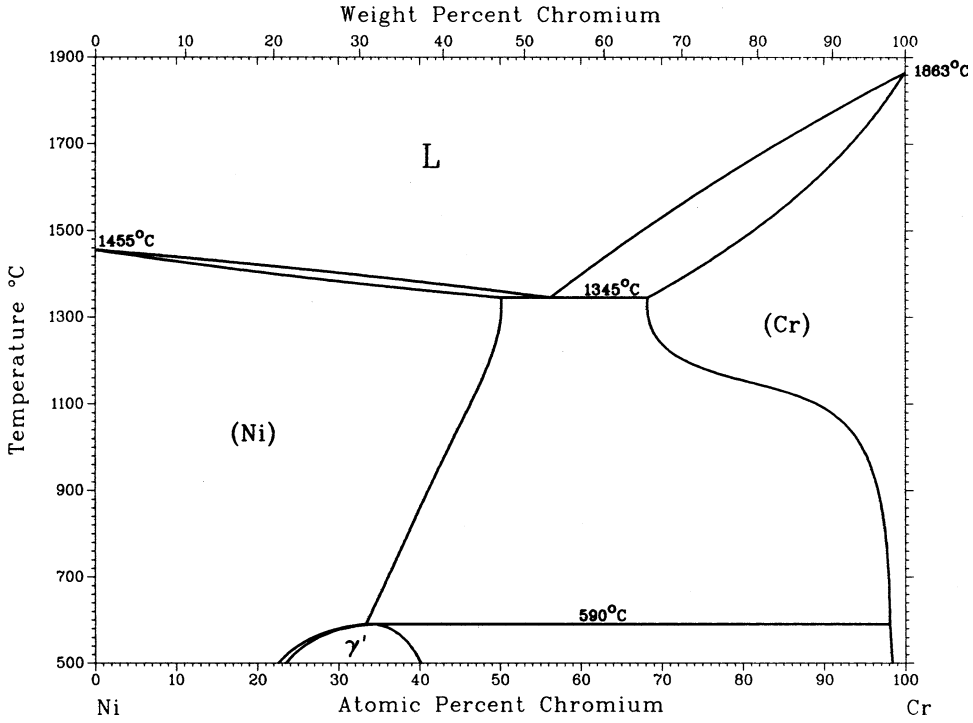

Fig. 2 The Cr-Ni system [1991Nas]

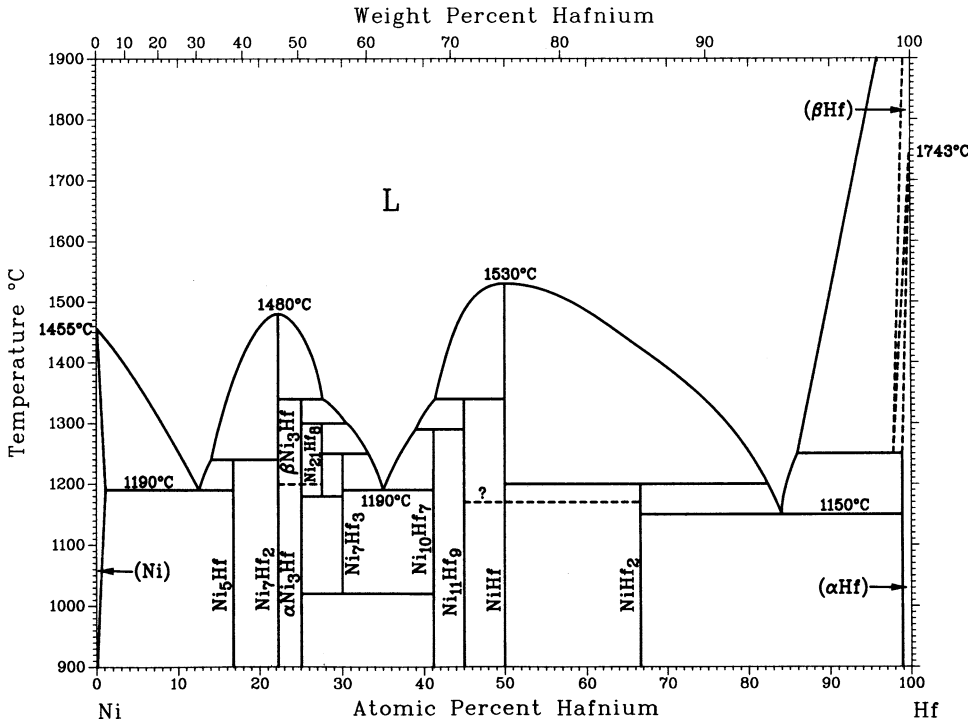

Fig. 3 The Ni-Hf system [1991Nas]

under argon atmosphere. The alloys in the as cast condition as well as in the 1227 °C annealed state were used to establish a partial isothermal section at 1227 °C and to establish an isopleths at constant 5 at.% Cr content. Optical metallography, x-ray diffraction (XRD), and thermal analysis were used for characterization of alloys.

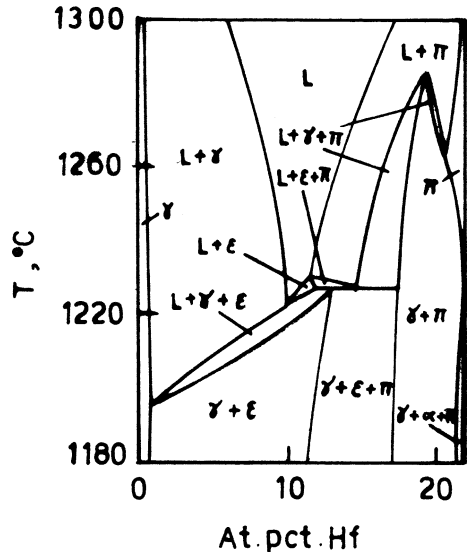

Fig. 4 A partial isopleth at constant 5 at.% Cr content [1999Kho]

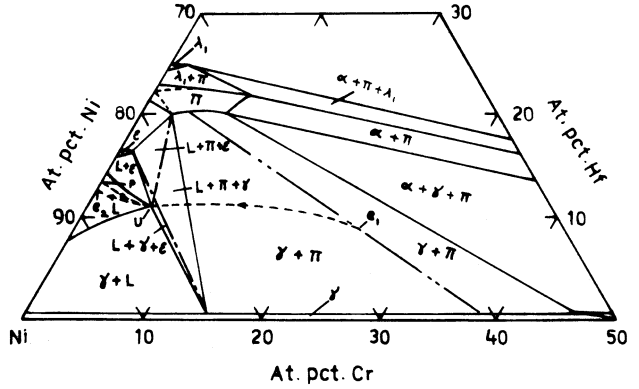

Fig. 5 A partial isothermal section of Cr-Hf-Ni system at 1227 °C at the Ni-corner. The π-γ pseudobinary line shown by _____ line. The four phase reaction plane indicated by crossed _____ lines. The dashed lines indicate the probable phase boundaries of the π phase

The isopleth at 5 at.% Cr content is given in Fig. 4. Figure 4 shows a four-phase reaction line at 1227 °C which agrees with that reported by [1998Nas]. The earlier reported pseudo-binary between the π and γ phases was also confirmed but the eutectic temperature was found to be 1290 °C, which is slightly higher than ~1270 °C reported by [1976Kim]. At 5 at.% Cr the lowest melting temperature of 1204 °C was found at ~10 at.% Hf.

The isothermal section at 1227 °C is given in Fig. 5. Figure 5 also shows the liquidus projection for the Ni-corner of the Cr-Hf-Ni system which is shown by dashed lines. The liquid composition from the $\pi - \gamma$ eutectic point e_1, reported to be at 24.5 at.% Cr and 9.2 at.% Hf by [1976Kim], interacts with liquid composition from the peritectic reaction p of the Hf-Ni system at U to give a four phase reaction $L + \pi \leftrightarrow \varepsilon + \gamma$ at 1227 °C. The reaction products of the four phase reaction below 1227 °C are $(\gamma + \pi + \varepsilon)$ and $(L + \gamma + \varepsilon)$. These three-phase regions were found and are given in Fig. 4. The last liquid finally solidifies at e_2 at the eutectic reaction $L \leftrightarrow \gamma + \varepsilon$ occurring in the Hf-Ni system. The liquidus projection of [1999Kho] agrees with that given in the review at the Cr-Hf-Ni system by [2001Gup]. The liquid composition at the four-phase reaction plane, i.e., at point ν, was found to be at 6 at.% Cr and 11.6 at.% Hf which agrees closely with the composition $Cr_{6.5}Hf_{10.5}Ni_{83}$ reported by [1981Nas]. The isothermal section also shows at higher Hf content region equilibrium of the π phase with the α phase. Two three phase regions $\alpha + \pi + \gamma$ and $\alpha + \pi + \lambda_1$ were found in equilibrium with a two-phase region $\alpha + \pi$ in between, as indicated in Fig. 5. This is in agreement with the isothermal section established at 1200 °C by [1981Nas]. The π phase is shown by [1999Kho] with a small solubility region at the Hf-Ni binary (Fig. 5) whereas the π phase is a single composition phase [1991Nas]. The probable phase boundaries of the π phase are shown in Fig. 5 by dashed lines.

References

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# indicates presence of phase diagram.

Cr-Ni-Hf evaluation contributed by **K.P. Gupta**, the Indian Institute of Metals, Metal House, Plot 13/4, Block AQ, Sector V, Calcutta, India. Literature searched through 1996. Dr. Gupta is the Alloy Phase Diagram Co-Category Program Editor for ternary nickel alloys.