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Al-Cr-Cu (Aluminum-Chromium-Copper)

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The compilation of [1995Vil] presented isothermal sections of this system at 600 °C for Al-rich alloys and at 20 °C for the whole composition range. Recently, [2006Gru] presented a brief critical review of these early results. Also, [2006Gru] investigated in detail the system between 1000 and 800 °C. They identified three ternary phases in the Al-rich region, but found no evidence for a quasicrystalline phase.

Binary Systems

The Al-Cr phase diagram depicts a number of intermediate phases with significant ranges of homogeneity: $CrAl_7$ (V_7Al_{45}-type monoclinic), Cr_2Al_{11} ($CrAl_5$-type monoclinic), $CrAl_4$ (hexagonal), Cr_2Al ($MoSi_2$-type tetragonal), and an unconfirmed low-temperature phase X at ~75 at.% Cr. Between 30 and 41 at.% Cr, five phases have been reported: αCr_4Al_9, βCr_4Al_9, γCr_4Al_9, αCr_5Al_8 and βCr_5Al_8, with no well-established phase boundaries between them [2000Mah]. Recent work by [2005Gru] confirmed the continuous nature of this region (denoted γ), separated into a high-temperature sub-region with the perfect γ-brass structure and a low-temperature sub-region with a distorted γ-brass structure. The Al-Cu phase diagram [1998Liu] depicts a number of intermediate phases: $CuAl_2$ ($C16$-type tetragonal, denoted θ), CuAl (η_1, orthorhombic) CuAl (η_2, monoclinic), Cu_5Al_4 (LT) (ζ, orthorhombic), ε_2 ($B8_2$, Ni_2In-type hexagonal), ε_1(bcc), Cu_3Al_2 (δ, rhombohedral), Cu_9Al_4(HT) (γ_0, $D8_2$, Cu_5Zn_8-type cubic), Cu_9Al_4(LT) (γ_1, $D8_3$-type cubic), and Cu_3Al (β, bcc). In the above, HT = high-temperature and LT = low-temperature. There are no intermediate phases in the Cr-Cu system.

Ternary Phases

[2006Gru] presented a critical review of the numerous references on the occurrence and thermal stability of quasicrystalline phases in this system. They pointed out that the previous references drew ternary isothermal sections on the basis of binary phase diagrams, which have since undergone significant changes. According to their detailed study, three ternary phases are stable in this system in the temperature range of 1000-800 °C, none of which is quasicrystalline. The phase denoted ζ has a hexagonal structure with lattice parameters of $a \approx 1.77$ nm and $c \approx 1.26$ nm. The Al and Cu ranges of ζ are 71-82 and 11-2 at.% respectively. The cubic κ phase (denoted in earlier references as β) has $a \approx 1.82$ nm and a composition range from about $Al_{65}Cu_{15}Cr_{20}$ to $Al_{58}Cu_{26}Cr_{16}$. The β phase has a primitive cubic structure (probably CsCl-type), with $a \approx 0.298$ nm and a composition of about $Al_{46}Cu_{36}Cr_{18}$.

Isothermal Sections

With starting metals of 99.999% Al, 99.95% Cu and 99.99% Cr, [2006Gru] levitation melted a number of ternary alloys under Ar atm. The alloys were annealed between 1000 and 800 °C for 24-570 h. The phase equilibria were studied with x-ray powder diffraction, electron diffraction in the transmission electron microscope, and scanning electron microscope with energy dispersive x-ray analysis. Differential thermal analysis was carried out at 2-20 °C/min. The isothermal sections constructed by [2006Gru] at 1000, 900 and 800 °C are shown in Fig. 1-3.

At 1000 °C (Fig. 1), no ternary phases were found. The Al-Cr binary phases (Cr), γ and $CrAl_4$ dissolve about 3, 9 and 2 at.% Cu, respectively. The Al-Cu binary phases (Cu), bcc and γ_0 dissolve up to ~0.5, 1 and 1 at.% Cr, respectively [2006Gru]. At 900 °C (Fig. 2), (Cr), γ, $CrAl_4$ and Cr_2Al_{11} phases dissolve up to ~2.5, 16, 1 and 1 at.% Cu, respectively. The ternary phase ζ ranges between $Al_{80.5}Cu_3Cr_{16.5}$, $Al_{76}Cu_{3.5}Cr_{20.5}$, and $Al_{72}Cu_{7.5}Cr_{20.5}$ compositions. The ternary β phase has a range between $Al_{45}Cu_{40}Cr_{15}$ and $Al_{47}Cu_{32}Cr_{21}$. At 800 °C (Fig. 3), the solubility of Cu in $CrAl_4$ and Cr_2Al_{11} phases is about the same as at 900 °C. The ternary β phase is not present. It decomposes between 900 and 800 °C probably through the ternary eutectoid reaction:

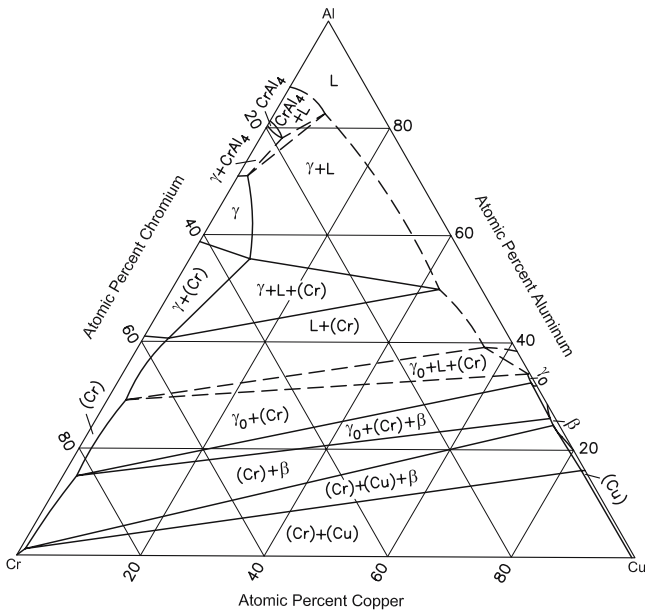

Fig. 1 Al-Cr-Cu isothermal section at 1000 °C [2006Gru]

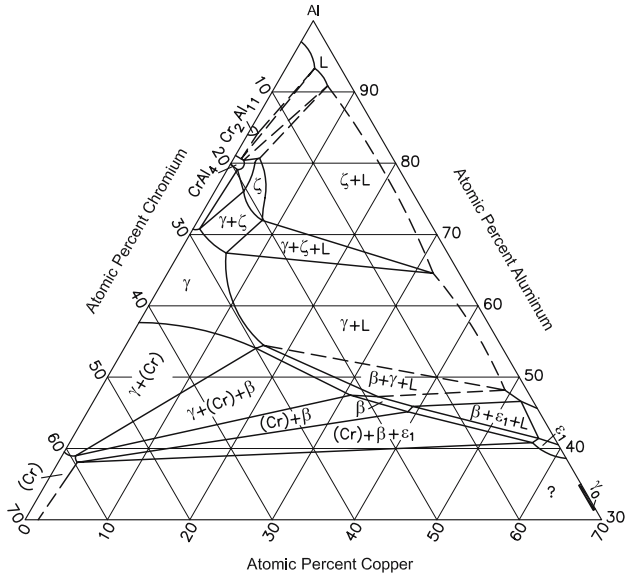

Fig. 2 Al-Cr-Cu isothermal section at 900 °C [2006Gru]

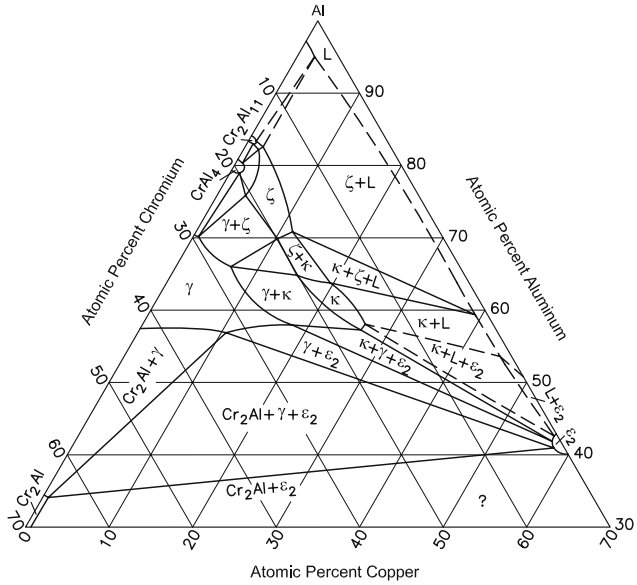

Fig. 3 Al-Cr-Cu isothermal section at 800 °C [2006Gru]

$\beta \leftrightarrow \gamma + \varepsilon_2 + Cr_2Al$ [2006Gru]. The ζ phase ranges between $Al_{82}Cu_2Cr_{16}$, $Al_{75}Cu_4Cr_{21}$ and $Al_{71}Cu_{11}Cr_{18}$. The κ phase ranges between $Al_{65}Cu_{15}Cr_{20}$, $Al_{64}Cu_{19}Cr_{17}$ and $Al_{58}Cu_{26}Cr_{16}$. The Al-Cr binary phase ν indicated by [2006Gru] between $CrAl_4$ and γ is not shown in Fig. 3.

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