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Al-Co-Cu (Aluminum-Cobalt-Copper)

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The early work on this system was summarized by [1995Vil]. Studies by Grushko and coworkers [1992Gru, 1993Gru, 2003Mi] have established the presence of several ternary phases in the Al-rich region of this system, in addition to the quasicrystalline decagonal phase D.

Binary Systems

The Al-rich region of the Al-Co phase diagram was reinvestigated by [1996God]. Three modifications of Co_4Al_{13}, all occurring in a narrow range of composition between 24 and 24.7 at.% Co, were found. The high-temperature Co_4Al_{13} (HT) (Os_4Al_{13}-type) is stable below 1127 °C and decomposes eutectoidally at 1083 °C to the orthorhombic form Co_4Al_{13}(o) and the monoclinic form Co_4Al_{13}(m). The other phases on the Al-rich side are: Co_2Al_9 ($D8_d$-type monoclinic), $CoAl_3$ ($D0_{11}$, Fe_3C-type orthorhombic), and Co_2Al_5 ($D8_{11}$-type hexagonal). On the Co-rich side, CoAl (*B*2, CsCl-type cubic) has a wide range of homogeneity from 48 to 78.5 at.% Co. The Al-Cu phase diagram [1998Liu] depicts a number of intermediate phases: $CuAl_2$ (θ, *C*16-type tetragonal), CuAl (η_1, orthorhombic) CuAl (η_2, monoclinic), Cu_5Al_4(LT) (ζ_2, orthorhombic), ε_1 (bcc), ε_2 ($B8_2$, Ni_2In-type hexagonal), 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. The Co-Cu phase diagram is a simple peritectic system, with no intermediate phases.

Ternary Isothermal Sections

The ternary phase Al_7Cu_2Co (denoted T) is tetragonal, space group *P*4/*mnc*, with lattice parameters a = 0.63047 nm and c = 1.4756 nm [1995Vil]. The ternary phase $Al_3(Cu,Co)_2$ (denoted H by [1992Gru] and τ_3 by [1993Gru]) is Ni_2Al_3-type hexagonal with lattice parameters of a = 0.4112 nm and c = 0.4958 nm [1991Gru]. A vacancy-ordered CsCl-type structure (denoted as *B*2′ here and as τ′ by [1993Gru]) is also known.

With starting metals of 99.999% Al, 99.9% Co, and 99.999% Cu, [2003Mi] induction melted about 25 Al-rich ternary alloys. The alloys were annealed at 900 °C for 85 h and quenched in water. The phase equilibria were studied with x-ray powder diffraction and scanning electron microscopy. Phase compositions were measured by energy dispersive x-ray analysis or by inductively coupled plasma optical emission spectroscopy. The isothermal section constructed by [2003Mi] at 900 °C is shown in Fig. 1. It is similar to that at 800 °C determined by [1992Gru] and [1993Gru]. The only ternary phase stable at this temperature is the quasicrystalline decagonal phase D. Its homogeneity region at 900 °C lies in the range of 65.5-68.5 at.% Al and 16.5-20.0 at.% Co. It is stable from 550 °C up to at least 1000 °C. At 900 °C, it forms tie-lines with liquid, Co_4Al_{13}(m), and CoAl (*B*2). Co_4Al_{13}(m) dissolves up to 6.5 at.% Cu at almost constant Co content [2003Mi].

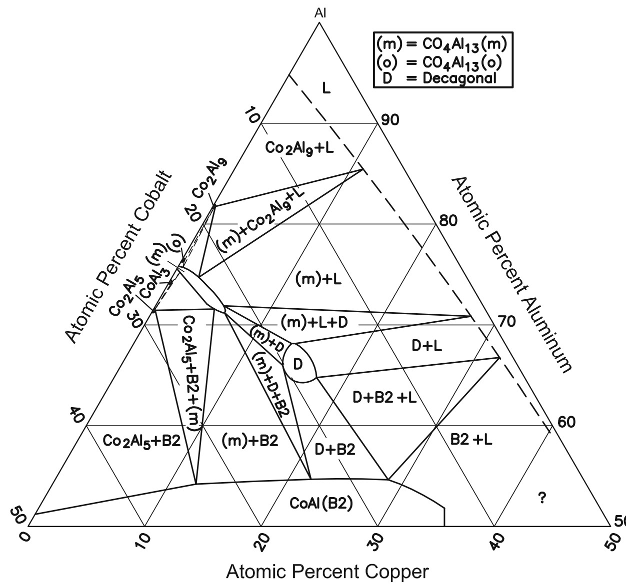

Fig. 1 Al-Co-Cu partial isothermal section at 900 °C [2003Mi]

[1993Gru] prepared 30 Al-rich ternary alloys by induction-melting under Ar atm. The alloys were annealed at 800 °C for 150-530 h or at 600 °C for 410-910 h and quenched in water. The partial isothermal sections at 800 and 600 °C constructed by [1993Gru] are shown in Fig. 2 and 3. At 800 °C (Fig. 2), only the decagonal D phase is present. At 600 °C (Fig. 3), the T (tetragonal), H (hexagonal), and B2′ (vacancy-ordered *B*2-type) phases are present, in addition to D. [1992Gru] reported partial equilibrium data at 1065, 1000, 900, 800, 700 and 550 °C. The partial diagram of [1992Gru] at 700 °C shows the presence of T and H phases at this temperature.

Recently, [2004Zha] determined the solidification characteristics of Al-rich alloys using Bridgman-grown crystals. Four ternary compositions close to the decagonal phase were pre-melted in an induction furnace under Ar atm. The compositions were selected such that each one lies in a different primary crystallization field, as determined by differential thermal analysis. The grown crystals were examined in three locations: the first-to-freeze part, the middle part, and the last-solidified part. Metallography, x-ray powder diffraction, and electron probe microanalysis

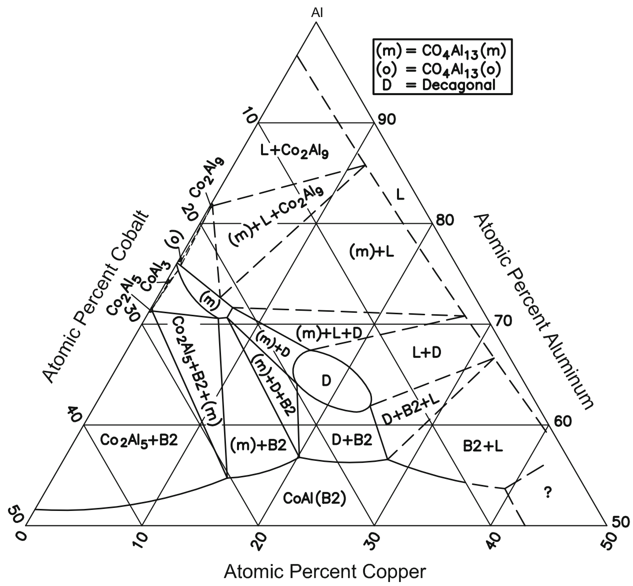

Fig. 2 Al-Co-Cu partial isothermal section at 800 °C [1993Gru]

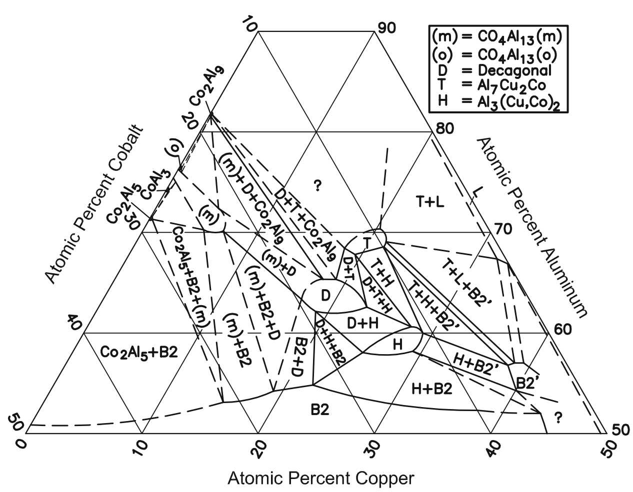

Fig. 3 Al-Co-Cu partial isothermal section at 600 °C [1993Gru]

were employed. The liquidus projection constructed by [2004Zha] for the Al-rich region is shown in Fig. 4. The two ternary peritectic reactions P_1 (1030 °C) and P_2 (770 °C) correspond to the formation of D and T phases, respectively. In addition, five U-type transition reactions and one ternary eutectic reaction E_1 (540 °C) are seen on the liquidus surface, Fig. 4. A reaction sequence incorporating the solidification reactions was given by [2004Zha].

A vertical section at 65 at.% Al, that is of interest for crystal growth of the decagonal phase, was determined by [2003Gil], Fig. 5. The invariant horizontals in Fig. 5 are labeled to match the nomenclature of the reactions in Fig. 4.

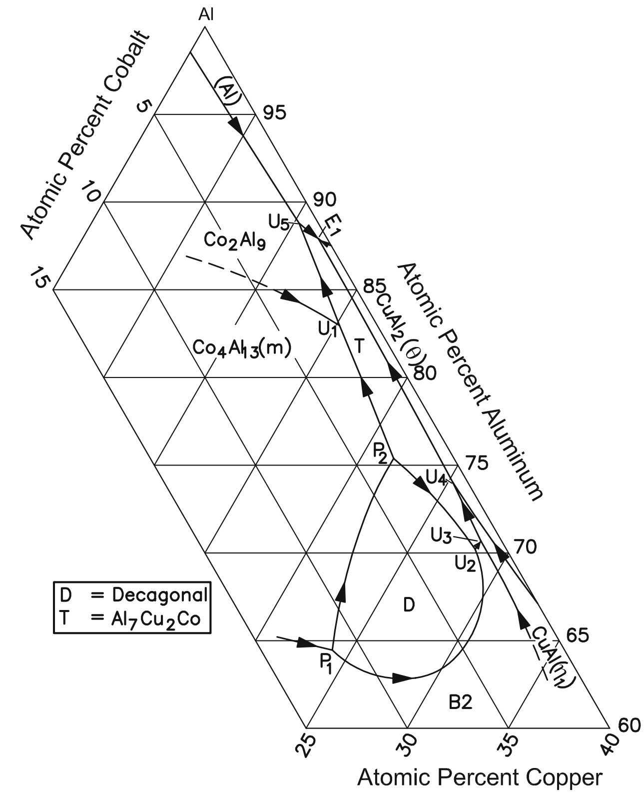

Fig. 4 Al-Co-Cu partial liquidus projection for Al-rich alloys [2004Zha]

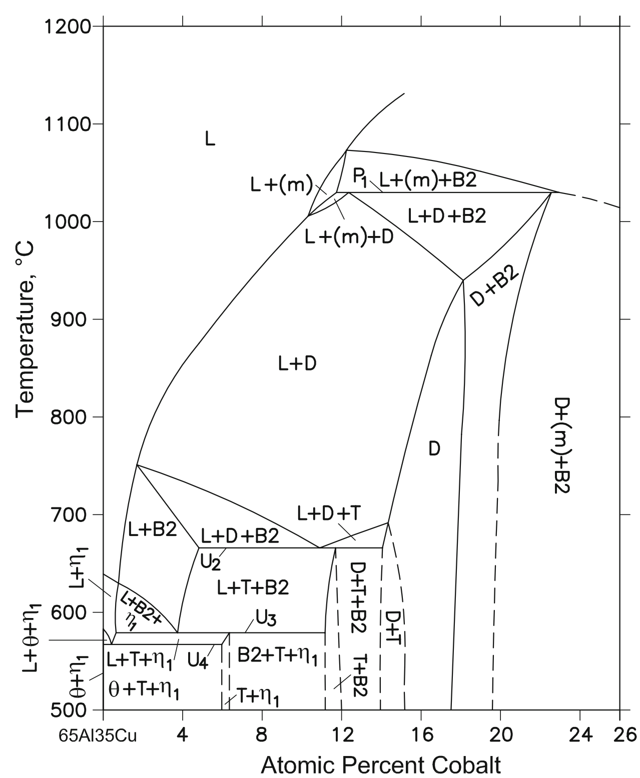

Fig. 5 Al-Co-Cu vertical section at 65 at.% Al [2003Gil]

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