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Al-Cu-Rh (Aluminum-Copper-Rhodium)

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The previous update on this system by [2008Rag] reviewed the results of [2000Gru], who had reported partial isothermal sections for Al-rich alloys at 900 and 800 °C. Recently, [2008Gru] extended this work and presented isothermal sections at 1010, 990, 900, 800, 700, 600, and 540 °C.

Binary Systems

The Al-Cu phase diagram [1998Liu] depicts a number of intermediate phases: $CuAl_2$ (*C*16-type tetragonal, denoted θ), CuAl (η_1, orthorhombic) CuAl (η_2, monoclinic), Cu_5Al_4 (LT) (ζ, orthorhombic), ε_2 ($B8_1$, NiAs-type hexagonal), ε_1 (bcc), Cu_3Al_2 (δ, rhombohedral), Cu_9Al_4 (HT) (γ_0, 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 Al-Rh phase diagram [2006Kho] depicts the following intermediate phases: Rh_2Al_9 ($D8_d, Co_2Al_9$-type monoclinic), $Rh_{1-x}Al_3$ (orthorhombic, denoted ε_{16}), $RhAl_3$ (orthorhombic, denoted ε_6), Rh_2Al_5 (c) (space group $Pm\bar{3}$, cubic, denoted C), Rh_2Al_5 (h) ($D8_{11}, Co_2Al_5$-type hexagonal, denoted H), Rh_3Al_7 (monoclinic, denoted V), and RhAl (*B*2, CsCl-type cubic, denoted β). The structurally related orthorhombic phases, ε_6 and ε_{16}, have two identical lattice parameters, with a differing third parameter and occur close to the composition $RhAl_3$. Cu and Rh form a continuous face-centered cubic (fcc) solid solution, with a miscibility gap below 1150 °C.

Ternary Phases

The Al-Rh binary phase C dissolves a significant amount of Cu. At the high Cu-limit of the C phase, the C_2 phase is

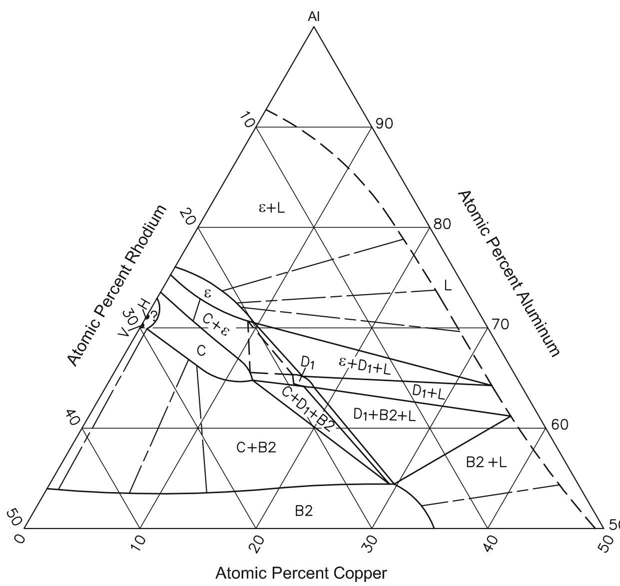

Fig. 2 Al-Cu-Rh partial isothermal section at 990 °C in the Al-rich region [2008Gru]

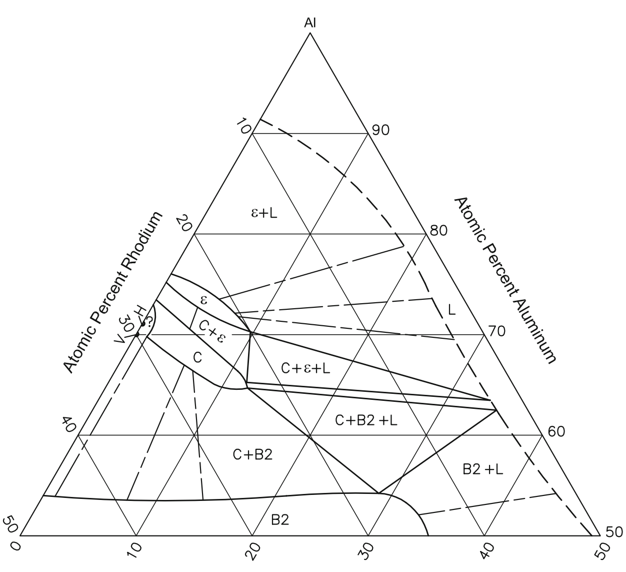

Fig. 1 Al-Cu-Rh partial isothermal section at 1010 °C in the Al-rich region [2008Gru]

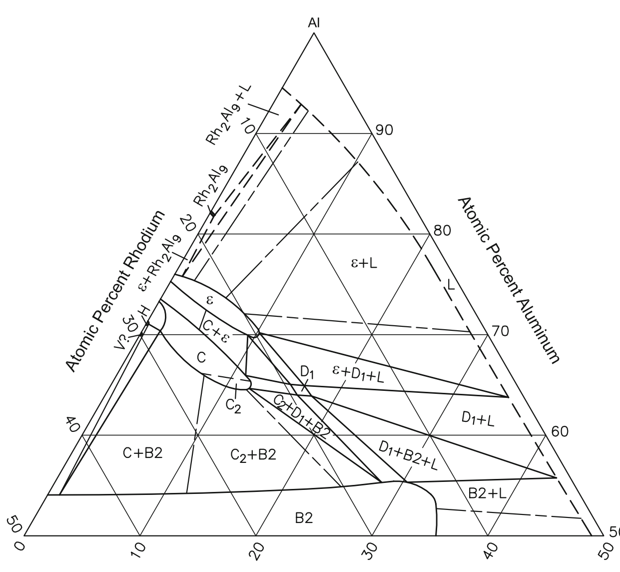

Fig. 3 Al-Cu-Rh partial isothermal section at 900 °C in the Al-rich region [2008Gru]

present at temperatures between 900 and 700 °C, with its cubic lattice parameter twice as large as that of the C phase. Even though this phase was labeled C_1 earlier by [2000Gru] and [2008Rag], it is relabeled as C_2 by [2008Gru], for consistency of the nomenclature of similar phases in other related systems [2007Gru]. No compositional gap was detected between C and C_2. The boundary between them is indicated by a broken line in the isothermal sections given below. Close to the C_2 phase, the decagonal phase D_1 is present. It forms from the melt at 1005 °C and is stable down to at least 600 °C. Its composition is around $Al_{64.2}Cu_{17}Rh_{18.8}$ at 990 °C and $Al_{62}Cu_{23}Rh_{15}$ at 600 °C. It has a basic periodicity of ~0.4 nm. Also, [2008Gru] noted weak diffuse reflections in the electron diffraction patterns, which corresponded to double or triple periodicity. At 660 °C, the ω phase forms peritectically in a small region around $Al_{70}Cu_{20}Rh_{10}$. It has tetragonal symmetry (space group *P*4/*mnc*) and lattice parameters of *a* = 0.6390 nm and *c* = 1.4798 nm.

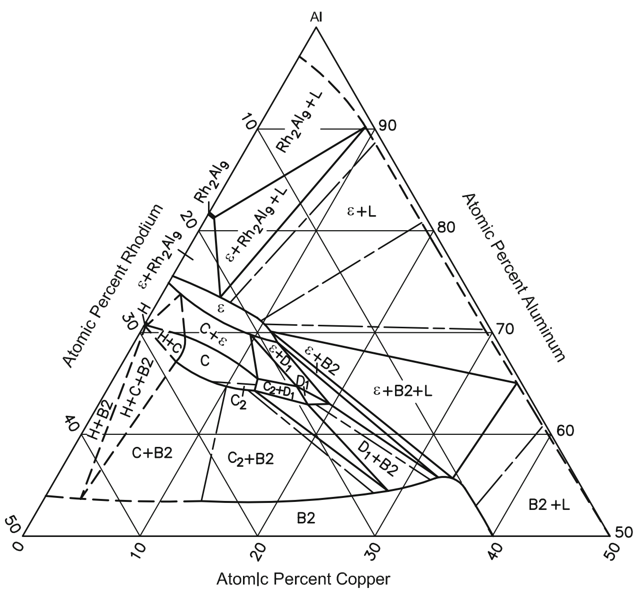

Fig. 4 Al-Cu-Rh partial isothermal section at 800 °C in the Al-rich region [2008Gru]

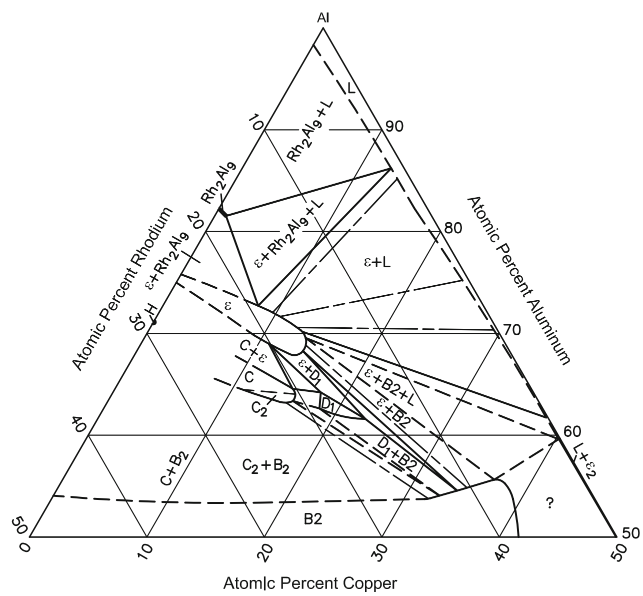

Fig. 5 Al-Cu-Rh partial isothermal section at 700 °C in the Al-rich region [2008Gru]

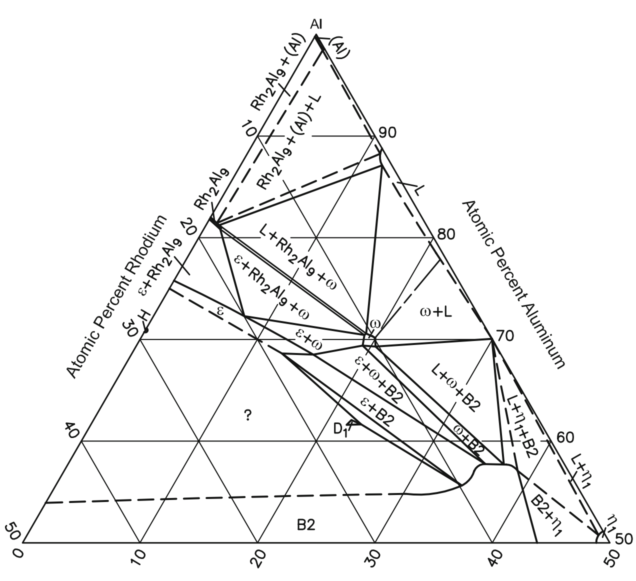

Fig. 6 Al-Cu-Rh partial isothermal section at 600 °C in the Al-rich region [2008Gru]

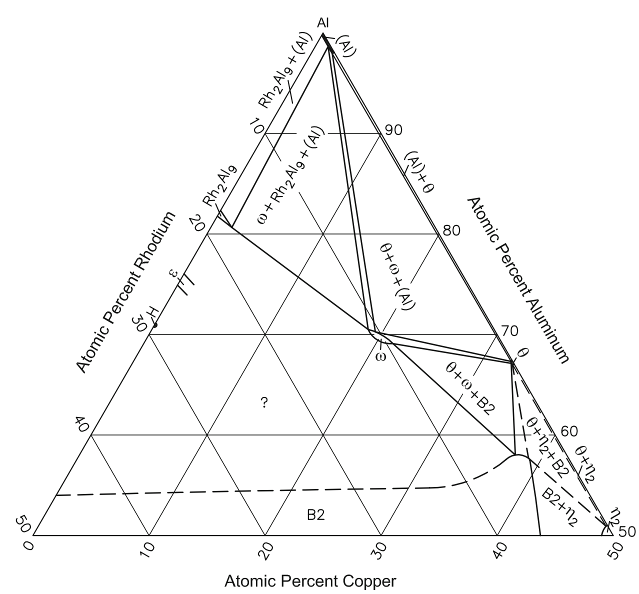

Fig. 7 Al-Cu-Rh partial isothermal section at 540 °C in the Al-rich region [2008Gru]

Isothermal Sections

[2008Gru] induction-melted alloy samples under Ar atm. The alloys were annealed at 1010-900 °C for 60-120 h, at 800 °C for 90-1400 h, at 700 °C for 40-2010 h, or at 600-540 °C for 65-2850 h, followed by water quenching. The phase equilibria were studied by x-ray powder diffraction, scanning and transmission electron microscopy, and differential thermal analysis at a heating or cooling rate of 10-50 °C per min. The phase compositions were determined by energy dispersive x-ray analysis and by inductively coupled optical emission spectroscopy.

The partial isothermal sections constructed by [2008Gru] in the Al-rich region between 1010 and 540 °C are shown in Fig. 1-7. The structural variants of the ε phase are coupled together as ε in the figures. At 1010 °C (Fig. 1), no ternary has appeared and only ternary extensions of the binary phases ε, C, and β (*B*2) are seen. At 990 °C (Fig. 2), the decagonal phase D_1 is present around the composition $Al_{64}Cu_{17}Rh_{19}$ and forms tie-lines with ε, C, β, and the liquid. The C, ε, and *B*2 phases dissolve 12, 10, and 35 at.% Cu, respectively. At 900 °C (Fig. 3) [2000Gru, 2008Gru], the C_2 phase is present at the high Cu-end of C. Rh_2Al_9 has appeared along the Al-Rh side. At 800 °C (Fig. 4) [2000Gru, 2008Gru], the V phase is no longer stable and the C phase has moved into the ternary region. At 700-540 °C (Fig. 5-7), the extension of the Al-Rh phases into the ternary region was not ascertained, as equilibrium could not be achieved in reasonable times. At 600 °C (Fig. 6), the Al-Cu η_1 phase and the ternary phase ω have appeared. The ω phase forms tie-lines with Rh_2Al_9, ε, *B*2, and liquid. At 540 °C (Fig. 7), the reported equilibria are more incomplete, as compared to 600 °C.

[2008Gru] compared the equilibrium features of this system with the Al-Co-Cu system and found several similarities between the ternary phases of the two systems.

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