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Ag-Al-Cu (Silver-Aluminum-Copper)

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A brief review of the data on this ternary system was given by [1980Cha]. Recently, [2005Wit] made a thermodynamic assessment of this system, using in the optimization their own thermochemical and phase equilibria measurements in conjunction with the published data. They computed 15 vertical sections, five isothermal sections and a liquidus projection.

Binary Systems

The Ag-Al phase diagram [Massalski2] depicts three intermediate phases: β (20.5-29.8 at.% Al; bcc), ζ (22.9-41.9 at.% Al; close-packed hexagonal (denoted ζ rather than δ to avoid confusion with δCu_3Al_2), and μ (~21-24 at.% Al; *A*13, αMn-type cubic). The Ag-Cu phase diagram is of the simple eutectic type, with the terminal phases (Ag) and (Cu) dissolving up to about 14 at.% Cu and 5 at.% Ag, respectively. 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),

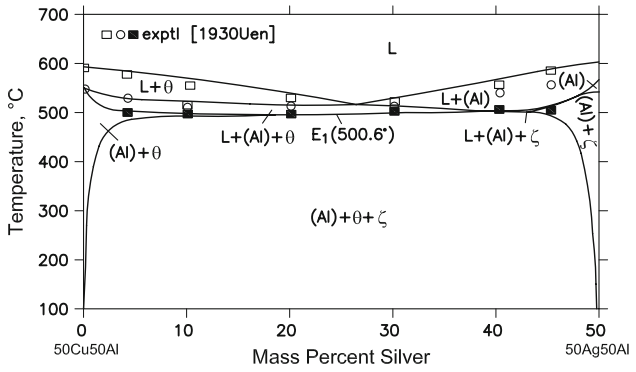

Fig. 1 Ag-Al-Cu computed vertical section at 50 mass% Al [2005Wit]

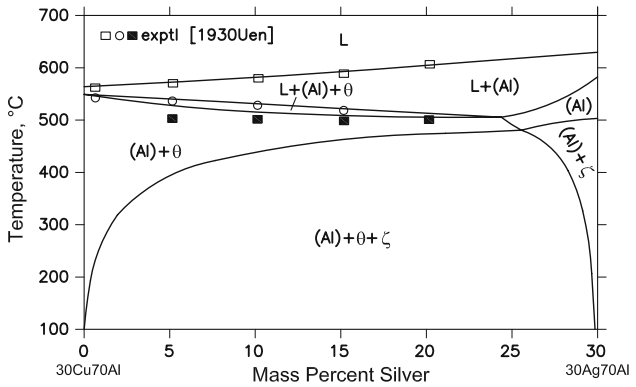

Fig. 2 Ag-Al-Cu computed vertical section at 70 mass% Al [2005Wit]

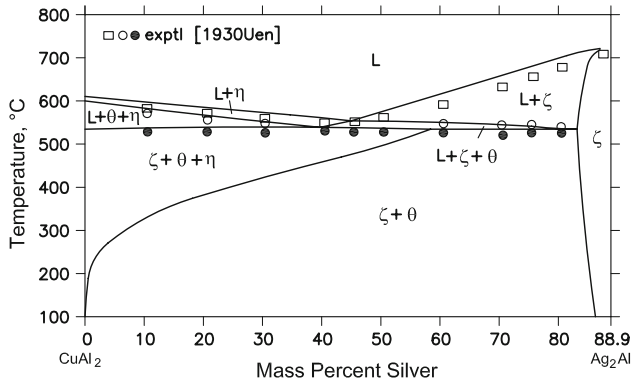

Fig. 3 Ag-Al-Cu computed vertical section along $CuAl_2$-Ag_2Al join [2005Wit]

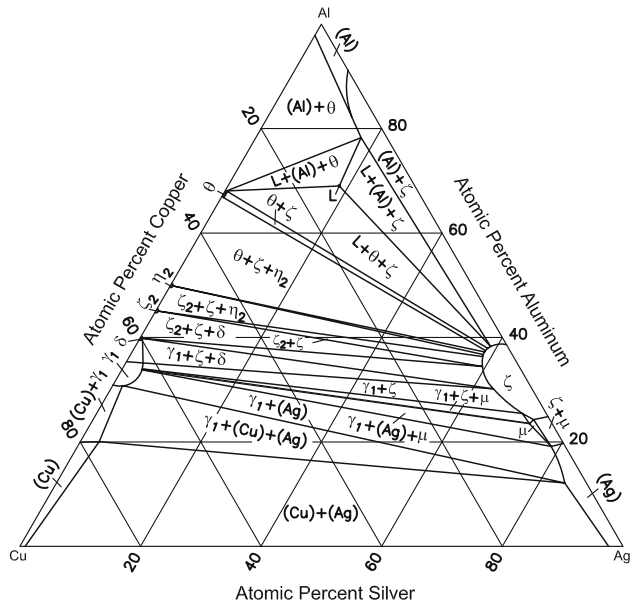

Fig. 4 Ag-Al-Cu computed isothermal section at 500.6 °C [2005Wit]

and Cu_3Al (β, bcc). In the above, HT = high-temperature and LT = low-temperature. Computed phase diagrams of the above binary systems were given by [2004Wit].

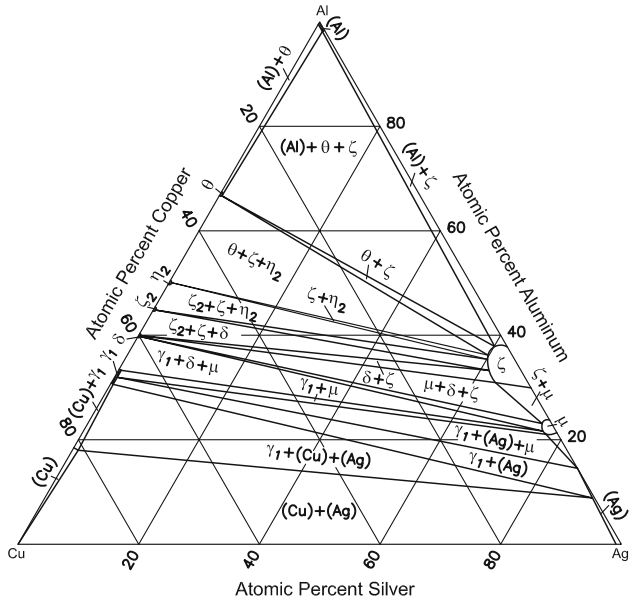

Fig. 5 Ag-Al-Cu computed isothermal section at 350 °C [2005Wit]

Ternary Phase Equilibria

With starting metals of 99.9998 % purity, [2005Wit] melted 7 ternary alloys with Al ranging from 44 to 79 at.% and Cu from 14 to 41 at.%. The enthalpy changes on heating were measured with differential scanning calorimetry (DSC). Isothermal equilibration of samples was done between 501 and 350 °C for 96-340 h, followed by water quenching. The compositions of the coexisting phases in the three-phase equilibria of (Al) + θ + ζ, η + θ + ζ, and γ_1 + μ + ζ were measured and listed at ~500 °C and additionally at 350 °C for (Al) + θ + ζ. A single tie-line for (Al) + ζ equilibrium was also measured.

The face-centered cubic, body-centered cubic, *A*13-type cubic, and close-packed hexagonal phases and the liquid solution were modeled as disordered solutions. Two sublattices were used for modeling δ, η, θ, and ζ phases. In the majority of cases, Cu was assumed to reside in the Ag sublattice. Three sublattices were used for γ_0 and γ_1 phases. For all the three binary subsystems, the earlier assessments of the authors [2004Wit] were used. The inputs for the optimization were the phase equilibrium data of [1930Uen], [1973Mas] and [2005Wit] and the thermochemical data of [2000Fla], [2002Wit], and [2005Wit]. Ternary interaction parameters were obtained from optimization for the liquid phase and the binary solid phases showing solubility of the third component.

[2005Wit] computed 15 vertical sections, 14 of which were compared with the experimental data of [1930Uen]. The vertical section along the $Ag_{0.1}Cu_{0.9}$-$Al_{0.1}Cu_{0.9}$ join

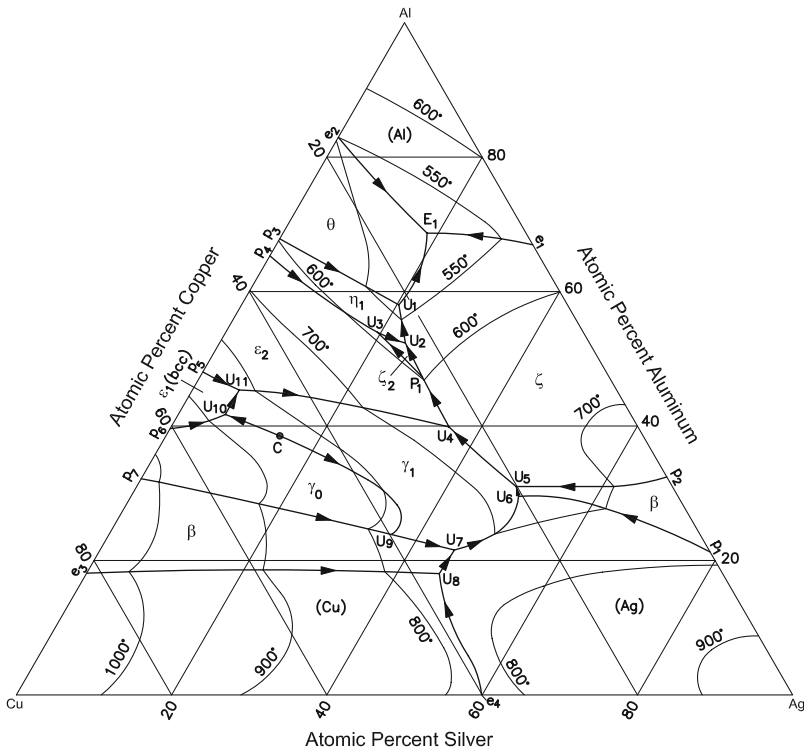

Fig. 6 Ag-Al-Cu computed liquidus projection [2005Wit]

was compared with the data of [1961Pan] and showed satisfactory agreement. The solid-liquid experimental points of [1930Uen] agreed well with the computed equilibria. However, a few points of solid-solid equilibria were not in good agreement. Three vertical sections at 50 and 70 wt.% Al and along the $CuAl_2$-Ag_2Al join, respectively are shown in Fig. 1-3 [2005Wit]. Isothermal sections computed at 625 and 575 °C were compared with the experimental sections of [1973Mas] and satisfactory agreement was found. The computed isothermal sections at 500.6 and 350 °C are shown in Fig. 4 and 5. They agree satisfactorily with a few experimental points of [2005Wit] (not shown) in the Al-rich region. The temperature of 500.6 °C (Fig. 4) corresponds to that of the ternary eutectic reaction: $L \leftrightarrow (Al) + \theta + \zeta$. The computed liquidus projection over the entire composition range is shown in Fig. 6. The nomenclature used by [2005Wit] for the invariant reactions is retained. The phases of primary crystallization are marked. The constant-temperature contour lines in Fig. 6 are in good agreement with the experimental data of [1930Uen] in the Al-rich region. More experimental results are required to validate the projection in the Al-lean region. [2005Wit] listed the computed temperatures and compositions of the coexisting phases in the invariant reactions depicted in Fig. 6. The temperature and composition of the ternary eutectic liquid E_1 are: 500.6 °C, 69.1 at.% Al, and 12.8 at.% Cu, in reasonable agreement with the reported experimental values.

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