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Al-Bi-Cu (Aluminum-Bismuth-Copper)

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Two previous reviews of this ternary system [1980Cha, 1992Kat] summarized the early work on this system. Recently, [2009Mir] carried out a thermodynamic analysis of this system, supplementing it with new experimental results.

Binary Systems

The Al-Bi system is characterized by a liquid miscibility gap that closes at 1034 °C [Massaslski2]. The Al-Cu phase diagram [1992Kat, 2009Mir] 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 ($B8_1$, NiAs-type hexagonal), β′, Cu_3Al_2 (δ, rhombohedral), Cu_9Al_4(HT) (γ′), Cu_9Al_4(LT) (γ, $D8_3$-type cubic), and Cu_3Al (β, bcc). In the above, HT = high-temperature and LT = low-temperature. The Bi-Cu phase diagram is of the simple eutectic type, with little solid solubility between Bi and Cu. Phase diagrams of the above binary systems were also reviewed by [1992Kat].

Ternary Phase Equilibria

With starting metals of 99.997% Al, 99.999% Bi and 99.99+% Cu, [2009Mir] levitation-melted 10 ternary alloys with Bi contents up to 32 at.%. The thermal arrests were determined by differential thermal analysis and differential scanning calorimetry. The phase identification and composition were determined by optical/scanning electron metallography and energy dispersive x-ray analysis. The thermal arrests and the interpretation based on the calculated phase boundary or invariant reaction were listed.

In their thermodynamic analysis, [2009Mir] used the binary descriptions of Al-Cu [1998Sau], Bi-Cu [1986Nie] and Al-Bi [1984McA] (Al-Bi modified by [2009Mir]). The Bi solubility in the Al-Cu intermediate compounds and the Al solubility in (Bi) were neglected. Only one ternary interaction parameter was introduced for the liquid phase.

The computed liquidus projection of [2009Mir] is shown in Fig. 1. The liquid miscibility gap originating in the Al-Bi side extends almost over the entire ternary region. The critical temperature of the ternary miscibility gap is at ~1630 °C. The univariant liquidus lines starting from the Al-Cu side intersect the liquid miscibility gap at very small concentrations of Bi and are not seen in Fig. 1. Figure 2 is schematic illustration of the miscibility gap, showing the four-phase invariant reactions that occur near the Al-Cu side. Reaction E_2 of [2009Mir] is relabeled as M. The Al-Cu phases γ and δ nucleate in the ternary region through the peritectic reactions P_1 and P_2. Several invariant reactions crowd near the Bi corner. Before the final solidification through the reaction L ↔ (Al) + (Bi) + θ occurs close to the Bi corner at 270.1 °C, five transition-type reactions labeled U_{11} through U_{15} are computed by [2009Mir] to occur within a range of 1 °C. These are not seen in Fig. 1 or 2.

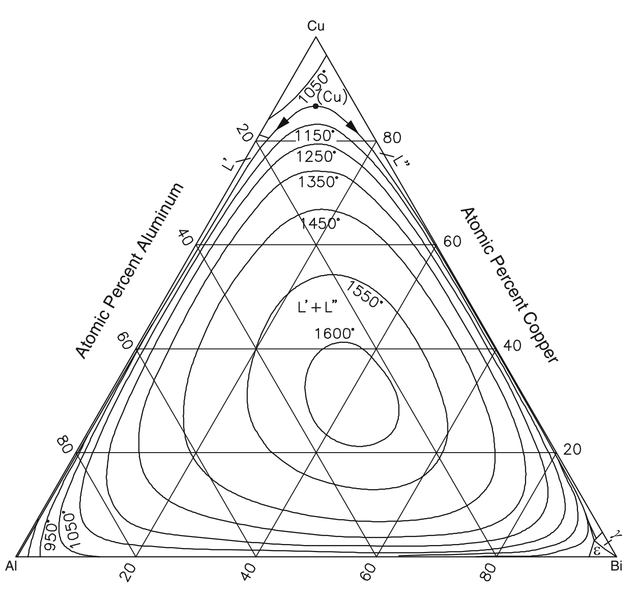

Fig. 1 Al-Bi-Cu computed liquidus projection [2009Mir]

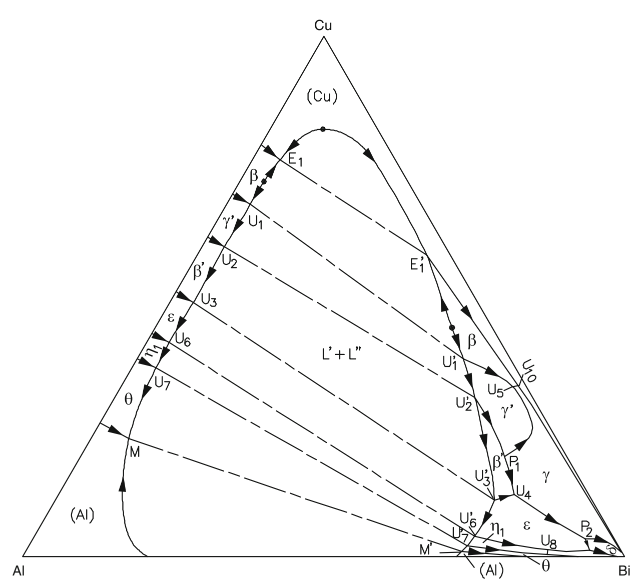

Fig. 2 Al-Bi-Cu schematic liquidus projection [2009Mir]

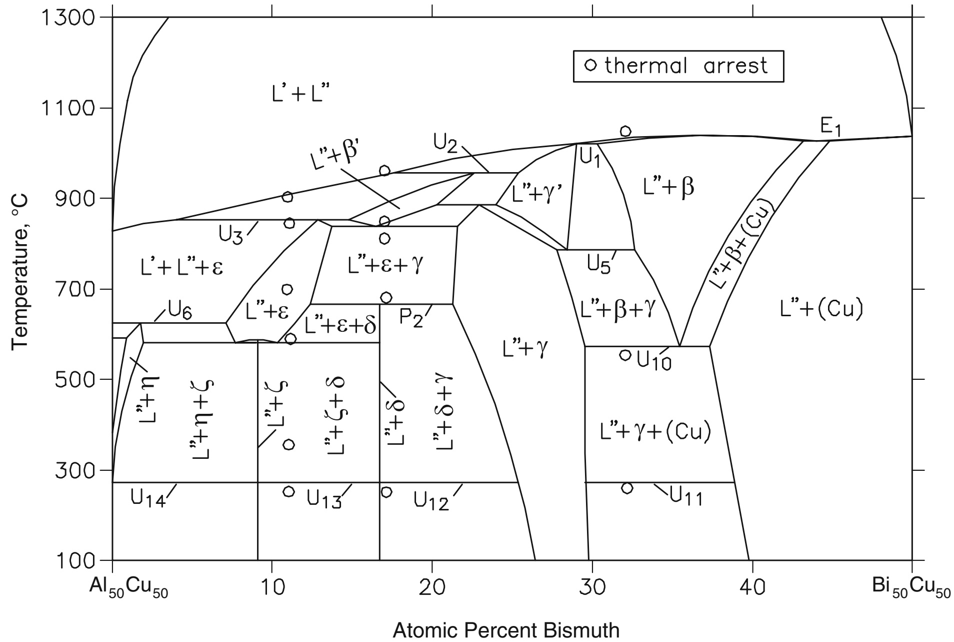

Fig. 3 Al-Bi-Cu computed vertical section at 50 at.% Cu [2009Mir]

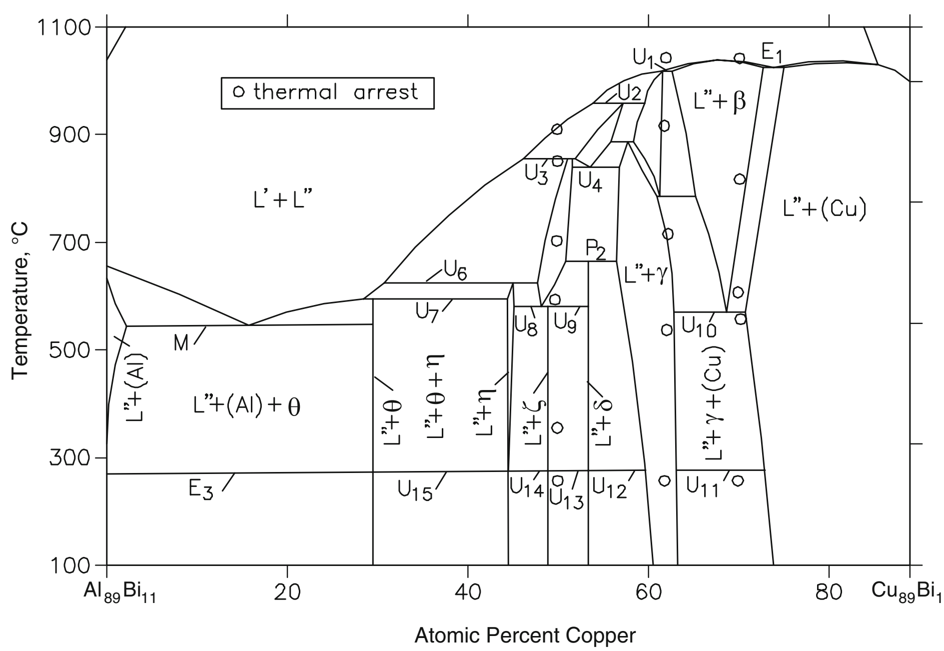

Fig. 4 Al-Bi-Cu computed vertical section at 11 at.% Bi [2009Mir]

[2009Mir] computed four vertical sections at 50, 62 and 71 at.% Cu and at 11 at.% Bi respectively. These sections were compared with the experimental data. As examples, two vertical sections at 50 at.% Cu and 11 at.% Bi are redrawn in Fig. 3 and 4. The agreement with the thermal arrests is satisfactory and lends credence to the interpretation of the data based on the calculations.

References

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