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Al-Ce-Cu (Aluminum-Cerium-Copper)

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[2004Ria] presented a comprehensive review of the Al-Cu-RE systems, which includes this system. They gave a partial liquidus surface and an isothermal section at 400 °C and the structural details of the known ternary compounds. [1991Yun] reported four pseudobinary sections and a liquidus surface in the Al-rich region. More recently, [2006Bel] determined three vertical sections for Al-rich alloys.

Binary Systems

The Al-Ce phase diagram was recently reassessed thermodynamically by [2005Gao], using new experimental results as additional input. The intermediate phases in this system are: αCe_3Al ($D0_{19}$, Ni_3Sn-type hexagonal), βCe_3Al ($L1_2$, $AuCu_3$-type cubic), Ce_2Al (stable between 775 and 648 °C; Co_2Si-type orthorhombic?), CeAl (orthorhombic), $CeAl_2$ ($C15$, $MgCu_2$-type cubic), $\alpha CeAl_3$ (Ni_3Sn-type hexagonal), $\beta CeAl_3$ (stable between 1192 and 973 °C), $CeAl_4$ or βCe_3Al_{11} ($D1_3$, Al_4Ba-type tetragonal), and αCe_3Al_{11} (αLa_3Al_{11}-type orthorhombic). 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. The Ce-Cu phase diagram [Massaslki2] has the following intermediate phases: Cu_6Ce (orthorhombic, space group *Pnma*), Cu_5Ce ($D2_d$, $CaCu_5$-type hexagonal), Cu_4Ce (orthorhombic, space group *Pnnm*), Cu_2Ce (orthorhombic, space group *Imma*), and CuCe ($B27$, FeB-type orthorhombic).

Ternary Phase Equilibria

For a listing of the known ternary phases of this system, see [2004Ria]. In the Al-rich alloys of interest here, two ternary phases occur: Al_8Cu_4Ce (denoted τ_1 here; $D2_b$, $ThMn_{12}$-type tetragonal) and Al_4CuCe (or Al_3CuCe; denoted τ_2 here). The latter phase was originally described as the Al_4Ba-type; in the fully-ordered state, it is of the $BaNiSn_3$-type [2004Ria].

Starting with high purity metals, [1991Yun] vacuum-melted a number of Al-rich alloys under Ar atm. The alloys were annealed at 500 °C for 240 h and quenched in water. Metallographic examination and differential thermal analysis (DTA) were carried out. Four pseudobinary sections were constructed along Al-τ_1, Al-τ_2, τ_1-τ_2, and τ_2-$CeAl_2$ joins. The first two sections, shown in Fig. 1 and 2, are of the simple eutectic type, with the eutectic temperatures at 585 and 595 °C, respectively. The ternary compounds τ_1 and τ_2 melt congruently at 925 and 1230 °C. The τ_1-τ_2 and τ_2-$CeAl_2$ sections (not shown here) are also of the eutectic type, with the eutectic temperatures at 850 and 1220 °C, respectively. Based on the DTA results, [1991Yun] constructed a liquidus surface, which divides the Al-rich region into three parts, the solidification in each part taking place through a ternary eutectic reaction. [2004Ria] presented a corrected form of this liquidus surface.

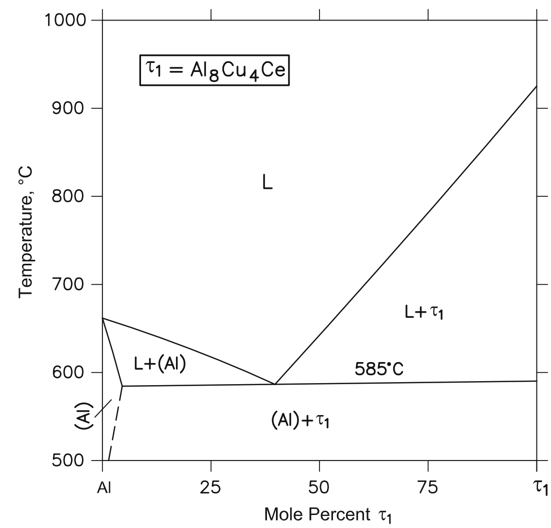

Fig. 1 Al-Ce-Cu pseudobinary section along the Al-τ_1 join [1991Yun]

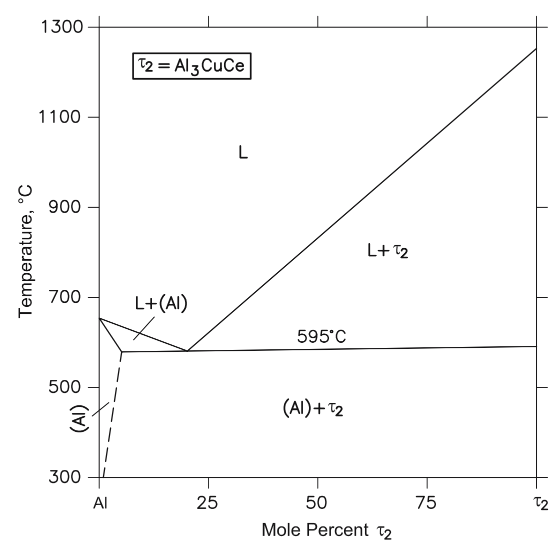

Fig. 2 Al-Ce-Cu pseudobinary section along the Al-τ_2 join [1991Yun]

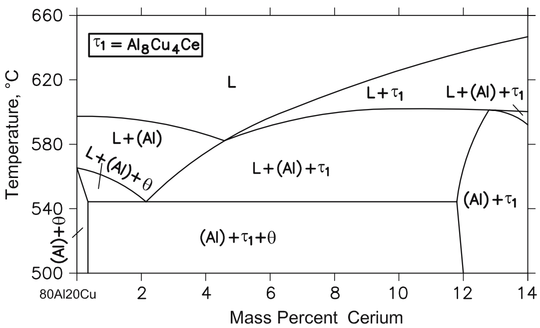

Fig. 3 Al-Ce-Cu vertical section at 20 mass% Cu [2006Bel]

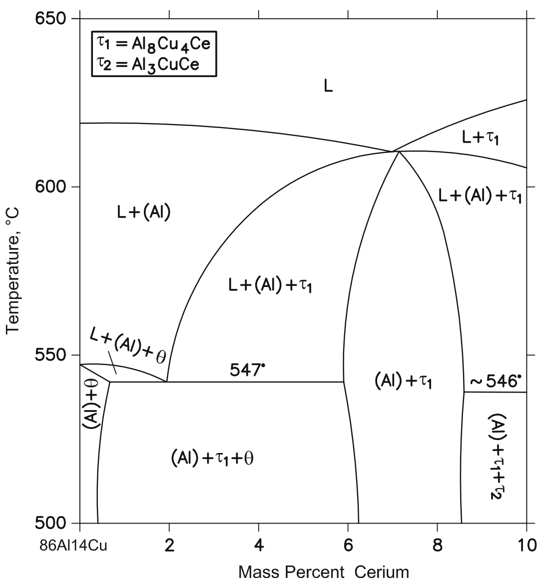

Fig. 4 Al-Ce-Cu vertical section at 14 mass% Cu [2006Bel]

With starting metals of 99.99% Al, 99.9% Ce and 99.9% Cu, [2006Bel] melted about 30 alloys in a resistance furnace, with the alloy compositions close to the L ↔ (Al) + τ_1 line. The phase equilibria were studied with optical and scanning electron microscope, x-ray diffraction and electron probe microanalysis. Thermal analysis and differential scanning calorimetry techniques were also employed. [2006Bel] confirmed the pseudobinary nature of the Al-τ_1 section. The measured eutectic temperature of this section was found to be 610 °C, as compared to 585 °C by [1991Yun]. The eutectic composition was 14Cu-7Ce (mass%). Two more vertical sections at 20 and 14 mass% Cu, respectively constructed by [2006Bel] are shown in Fig. 3 and 4.

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