JPEDAV (2005) 26:57-58
DOI: 10.1361/15477030522491
1547-7037/$19.00 ©ASM International

Al-Co-Fe (Aluminum-Cobalt-Iron)

V. Raghavan

[1988Ray] reviewed the phase relationships in this system and presented two partial liquidus surfaces, one for Al-poor Fe-Co alloys and the other for Al-rich alloys, an isothermal section at 800 °C for Co-rich alloys, and isothermal sections at 640 and 600 °C for alloys near the Al corner. A full isothermal section at 650 °C from [1999Koz] and a partial section at 1127 °C were reviewed in the update by [2002Rag]. More recently, [2004Kam] determined the phase relationships in Co-rich alloys between 1200 and 900 °C in the region of the magnetic and order-disorder transitions.

Binary Systems

The Al-Co phase diagram was reviewed by [1989McA]. On the Al-rich side, four intermediate phases occur: Al_9Co_2, $Al_{13}Co_4$, Al_3Co, and Al_5Co_2. With increasing Co, AlCo with the CsCl-type *B*2 ordered structure is stable over a wide composition and temperature range. In the Fe-Al phase diagram [1993Kat], the solid solution based on face-centered cubic (fcc) Fe is restricted by a γ loop. The solid solution based on body-centered cubic (bcc) Fe (α) exists in both the disordered (*A*2) and the ordered (*B*2 and $D0_3$) forms. The α(*A*2) → *B*2 transition is second order down to ~600 °C; below that, a two-phase field of (α + *B*2) intervenes, which is indicative of a first-order transition. Apart from the high-temperature phase ε, there are three intermediate phases in the system with restricted ranges of homogeneity: $FeAl_2$, Fe_2Al_5, and $FeAl_3$ (or Fe_4Al_{13}). In the Co-Fe system [1984Nis], the fcc form of Fe forms a continuous solid solution γ with fcc Co over a wide range of temperatures. The γ → α (bcc) transformation temperature in Fe is initially raised by the addition of Co, reaching a maximum of 985 °C at 45 at.% Co. At 730 °C, the bcc phase of equiatomic composition orders to a *B*2 structure via a second-order transition. For crystal structure data on the above binary compounds, see [Pearson3].

Ternary Phase Equilibria

Using starting metals of purity 99.7% Al, 99.9% Co, and 99.95% Fe, [2004Kam] induction melted about 15 alloys under an Ar atmosphere. The final anneal was between 1200 and 900 °C for 4 to 21 days, followed by quenching in an ice-water mixture. The phase equilibria were studied by metallography, electron probe microanalysis, transmission electron microscopy, and differential scanning calorimetry. As the *A*2 → *B*2 transition could not be suppressed by quenching, the existence of the *A*2 phase at high temperatures was deduced from the small size of the antiphase domains that were obtained on quenching. Similarly, the existence of the fcc solid solution γ at high temperatures was deduced from the high dislocation density within the bcc phase transformed martensitically on quenching. Four isothermal sections constructed by [2004Kam] for Co-rich alloys at 1200 to 900 °C are shown in Fig. 1 and 2. At 1200 °C (Fig. 1a), the (γ + *B*2) equilibrium extends into the ternary from the Co-Al side. As the Fe content increases, at lower Al contents, a narrow γ + α(*A*2) field becomes stable. At higher Al contents, the ordered *B*2 phase is stable, with no two-phase field between α and *B*2. At 1100 °C (Fig. 1b), the phase equilibrium is similar to that at 1200 °C. At 1000 °C (Fig. 2a), the (γ + *B*2) field extends to higher Fe contents. A part of the *B*2 field above the α field is ferromagnetic. At 900 °C (Fig. 2b), the area occupied by the ferromagnetic part of the *B*2 field is quite large. The vertical sections at 30 and 50 at.% Fe (Fig. 3) depict the Curie temperature (T_C) for the para → ferro (magnetic) transition.

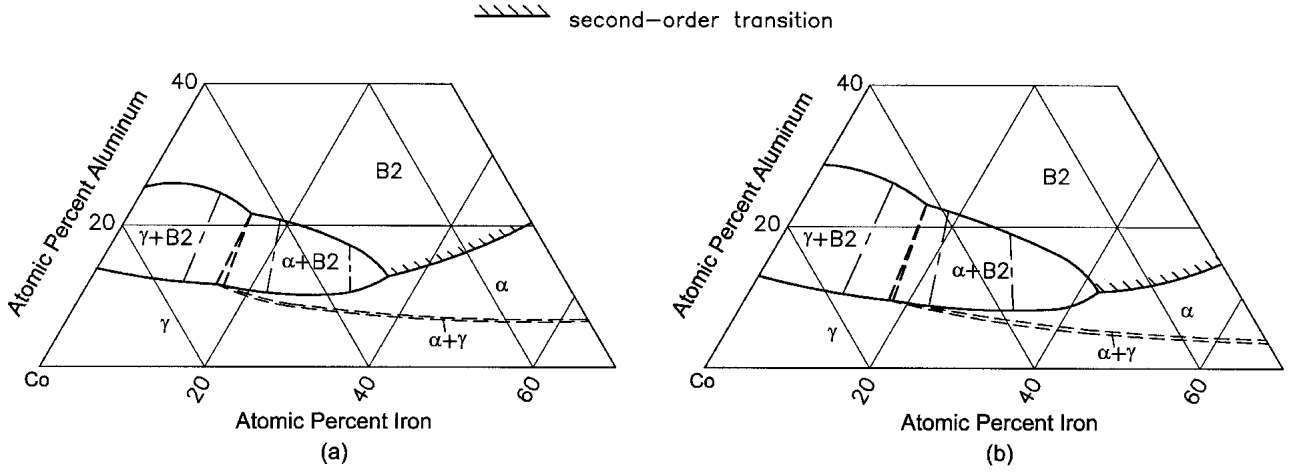

Fig. 1 Al-Co-Fe isothermal sections at (a) 1200 °C and (b) 1100 °C [2004Kam]

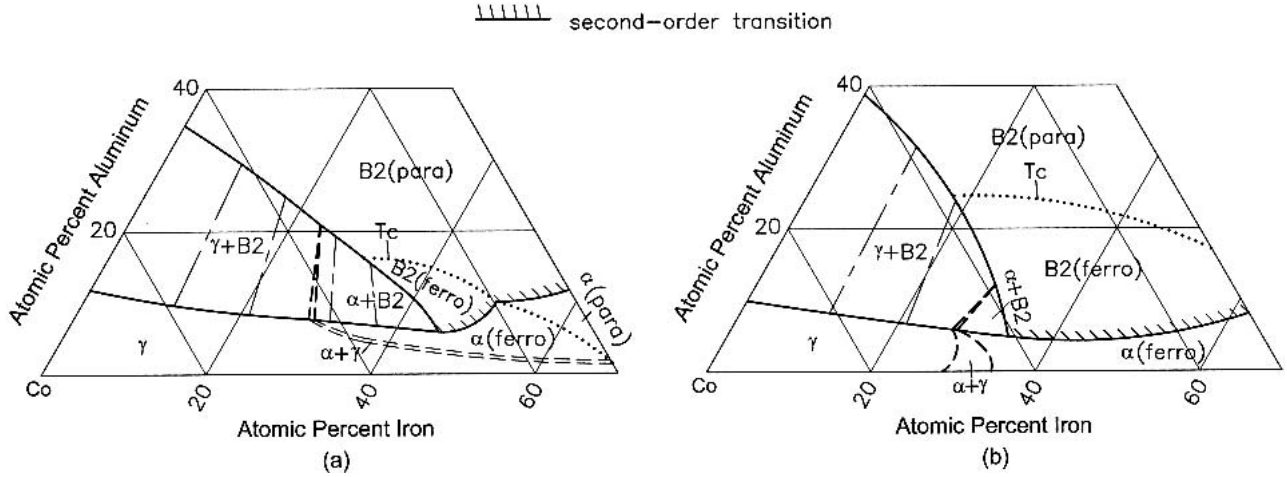

Fig. 2 Al-Co-Fe isothermal sections at (a) 1000 °C and (b) 900 °C [2004Kam]

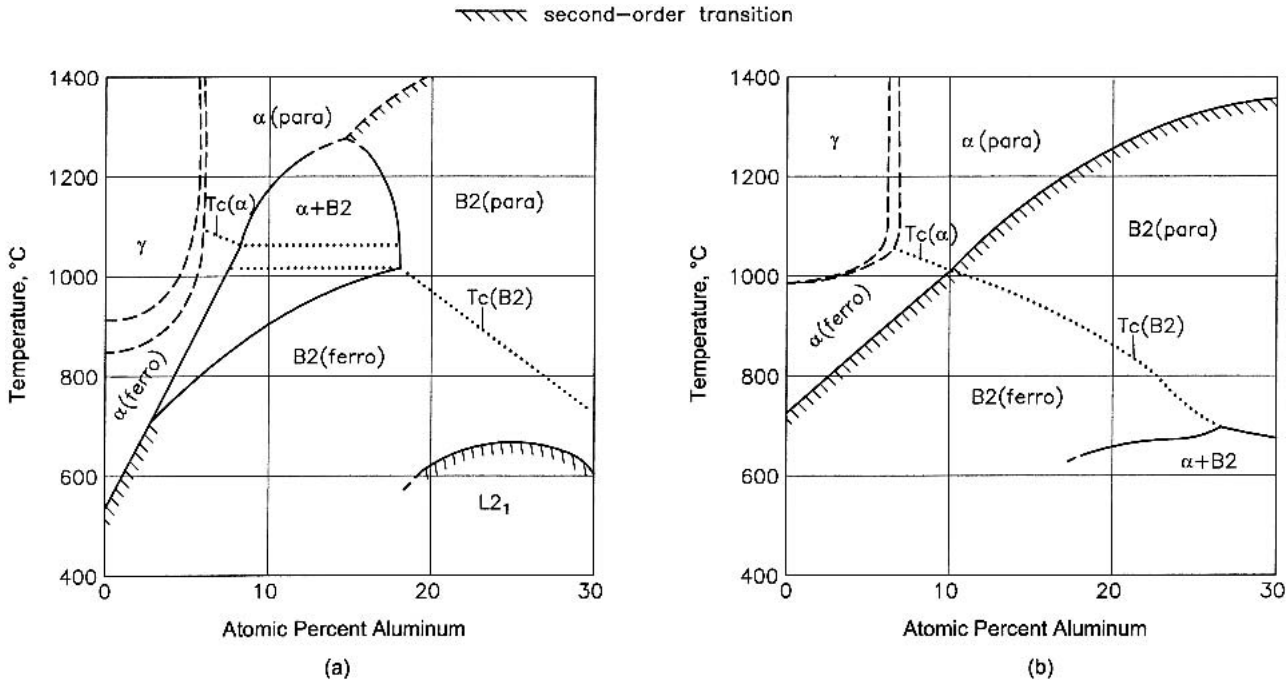

Fig. 3 Al-Co-Fe vertical sections at (a) 30 at.% Fe and (b) 50 at.% Fe [2004Kam]

The T_C of α lies above the T_C of the ordered *B*2 phase in Fig. 3(a). At a constant Fe content of 50 at.% (Fig. 3b), the (α + *B*2) two-phase field disappears and the two T_C values are continuous across the second-order phase boundary between α and *B*2, with a slight change in the slope at the boundary. Also, [2004Kam] determined the partition coefficients of Fe and Al and found that Al segregates preferentially to the *B*2 phase containing Fe up to ~25 at.%, when the *B*2 phase is in equilibrium with either γ or α.

References

1984Nis: T. Nishizawa and K. Ishida, The Co-Fe (Cobalt-Iron) System, *Bull. Alloy Phase Diagrams,* Vol 5 (No. 3), 1984, p 250-259

1988Ray: G.V. Raynor and V.G. Rivlin, Al-Co-Fe, *Phase Equilibria in Iron Ternary Alloys,* Institute of Metals, London, 1988, p 71-81

1989McA: A.J. McAlister, The Al-Co (Aluminum-Cobalt) System, *Bull. Alloy Phase Diagrams,* Vol 10 (No. 6), 1989, p 646-650

1993Kat: U.R. Kattner and B.P. Burton, Al-Fe (Aluminum-Iron), *Phase Diagrams of Binary Iron Alloys,* H. Okamoto, Ed., ASM International, 1993, p12-28

1999Koz: T. Kozakai and T. Miyazaki, Phase Equilibria in the Fe-Al-Co Ternary System at 923 K, *Z. Metallkde.,* Vol 90 (No. 4), 1999, p 261-266

2002Rag: V. Raghavan, Al-Co-Fe (Aluminum-Cobalt-Iron), *J. Phase Equilibria,* Vol 23 (No. 5), 2002, p 434-436

2004Kam: N. Kamiya, T. Sakai, R. Kainuma, I. Ohnuma, and K. Ishida, Phase Separation of BCC Phase in the Co-Rich Portion of Co-Fe-Al System, *Intermetallics,* Vol 12, 2004, p 417-423