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Al-Co-Si (Aluminum-Cobalt-Silicon)

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The previous reports on this system are by [1951Pra] (partial isothermal section at 536 °C for Al-rich alloys) and by [1981Her] (full isothermal section at 600 °C). Recently, [2005Ric] investigated the phase equilibria and reported three isothermal sections at 800 and 600 °C for Co-lean alloys and at 900 °C for Co-rich alloys.

Binary Systems

The Al-Co phase diagram [1996God] shows the following intermediate phases: CoAl (48-78.5 at.% Co; *B*2, CsCl-type cubic), Co_2Al_5 ($D8_{11}$-type hexagonal), $CoAl_3$ ($D0_{11}$, Fe_3C-type orthorhombic), Co_4Al_{13} (three modifications with one orthorhombic and two monoclinic forms), and Co_2Al_9 ($D8_d$-type monoclinic). The Al-Si phase diagram is a simple eutectic system with the eutectic reaction at 577 °C and 12.2 at.% Si. The Co-Si phase diagram [1991Ish] depicts the following intermediate phases: Co_3Si (tetragonal, stable between 1214 and 1193 °C), βCo_2Si (stable between 1334 and 1238 °C), αCo_2Si (*C*23, Co_2Si-type orthorhombic), CoSi (*B*20, FeSi-type cubic), and $CoSi_2$ (*C*1, CaF_2-type cubic). The (αCo) → (εCo) transition temperature is steeply raised to above 1200 °C by the addition of Si.

Ternary Phases

[2005Ric] presented the structural data on seven ternary phases of this system, by combining the previously-known

Table 1 Al-Co-Si crystal structure and lattice parameter data [2005Ric]

Phase	Composition, at.%	Pearson symbol	Space group	Prototype	Parameter Lattice, nm
$Co_3Al_{3.1-2.4}Si_{3.9-4.6}$ (τ_1 or α)	31-24 Al 30 Co 39-46 Si	*cI*40	$Im\bar{3}m$	Ge_7Ir_3	a = 0.8115 – 0.8072
$Co_4Al_{1.7-2.8}Si_{4.3-3.2}$ (a) (τ_2 or β)	17-28 Al 40 Co 43-32 Si	*hP*5	$P\bar{3}m1$	Ni_2Al_3	a = 0.3870 – 0.3885 c = 0.4758 – 0.4769
$Co_{19+x}Al_{43+y}Si_{12-y}$ ($0 \le x \le 0.7$; $-0.5 \le y \le 3$) (τ_3 or γ)	56.9-62.2 Al 25.7-26.4 Co 16.9-12.2 Si	*mC*296+	*C*2/*c*	...	a = 2.0040 b = 1.9170 c = 1.2826 γ = 123.591°
$Co_{32.5}Al_{40.5-43}Si_{27-24.5}$ (τ_4 or δ)	40.5-43 Al 32.5 Co 27-24.5 Si	*mC*?	...	...	a = 1.1851 b = 0.38838 c = 0.74293 γ = 103.17°
$Co_6Al_{11}Si_6$ (τ_5 or ε)	47.8 Al 26.1 Co 26.1 Si	*oC*184	$Cmc2_1$	...	a = 0.80839 b = 1.45445 c = 2.1354
$Co_4Al_{7+x}Si_{2-x}$ ($0.27 \le x \le 1.05$) (τ_6 or χ)	55.9-61.9 Al 30.8 Co 13.3-7.3 Si	*mC*26	*C*2/*m*	...	a = 1.19935 b = 0.40098 c = 0.76590 γ = 106.357°
$Co_{10+x}Al_{25-x}Si_7$ (x = 0.33) (τ_7 or φ)	58.7 Al 24.6 Co 16.7 Si	*oP*168	*Pnma*	...	a = 1.3846 b = 2.3050 c = 0.7336

(a) Co variation not indicated (see text)

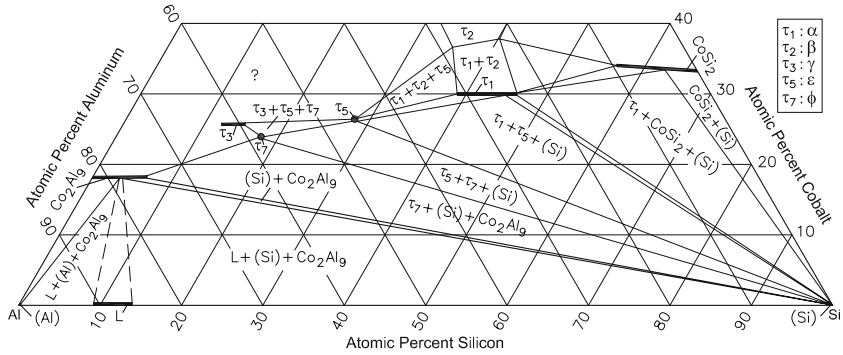

Fig. 1 Al-Co-Si partial isothermal section at 600 °C [2005Ric]. Narrow two-phase regions are omitted

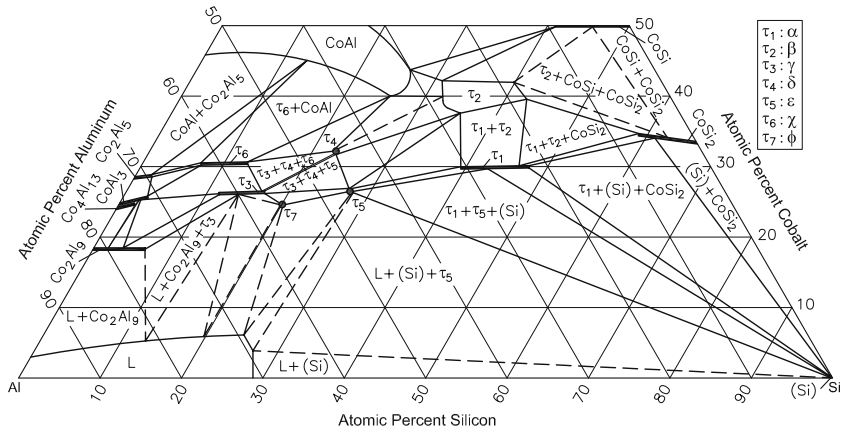

Fig. 2 Al-Co-Si isothermal section at 800 °C [2005Ric]. Narrow two-phase regions are omitted

data with their own work, see Table 1. The ternary phases are denoted here as τ_1, τ_2, τ_3, τ_4, τ_5, τ_6, and τ_7. They correspond to α, β, γ, δ, ε, χ, and ϕ, respectively in the nomenclature adopted by [2005Ric]. The phase τ_2 (β) shows a variation in the Co content of about ±2 at.% around the ideal value of 40 at.% [2005Ric].

Ternary Isothermal Sections

With starting metals of 99.999% Al, 99.9+% Co and 99.9999% Si, [2005Ric] arc-melted under Ar atm a total of 104 alloy compositions. A series of 28 samples with Co content up to 35 at.% were annealed at 600 °C for 4 weeks. A second series of 60 samples with Co content up to 50 at.% and in the Al-rich region, wherein lie the ternary phases τ_3, τ_4, τ_5, τ_6, and τ_7, were annealed at 800 °C for 4 weeks. A third series of 26 samples in the Co-rich region were annealed at 900 °C. The phase equilibria were studied with x-ray powder diffraction, metallography, and electron probe microanalysis.

Figure 1 shows the partial isothermal section at 600 °C constructed by [2005Ric]. The binary phases $CoSi_2$ and Co_2Al_9 dissolve up to 9.3 at.% Al and 6.6 at.% Si, respectively. The results of [2005Ric] showed that Si substitutes for Al in Co_2Al_9. Figure 2 is the isothermal section at 800 °C. The CoAl (*B*2) phase extends far into the ternary region. The ternary phases τ_4 (δ), τ_5(ε), and τ_7 (ϕ) are virtually stoichiometric. The Si ranges of τ_1 (α) and τ_6(χ) are 39-46 and 7.3-13.3 at.%, respectively (at constant Co content). The homogeneity regions of τ_2(β) has a more complex spread. Figure 3 shows the isothermal section constructed by [2005Ric] in the Co-rich region. The (εCo) phase stabilized by Si dissolves very little Al. CoSi dissolves up to 11.5 at.% Al, whereas the solubility in Co_2Si is only 2.7 at.%. The CoAl (*B*2) phase extends up to 73 at.% Co, as compared with its extension up to 61 at.% Co in the Al-Co binary system. [2005Ric] reported detailed measurements of the lattice parameters of the binary and ternary solid solutions.

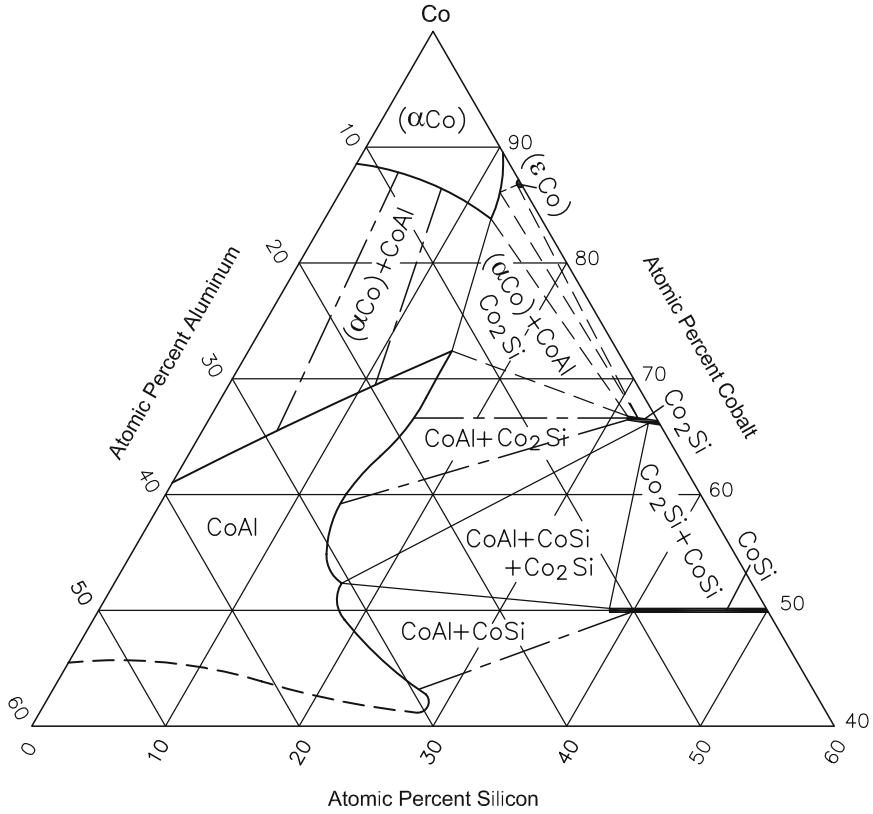

Fig. 3 Al-Co-Si isothermal section at 900 °C [2005Ric]

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