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Al-Co-Pd (Aluminum-Cobalt-Palladium)

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Recent investigations of this system [2000Yur, 2002Yur] have revealed the existence of a number of ternary compounds in the Al-rich region. A comparative study of the Al-Co-Pd and Al-Co-Ni systems was presented by [2004Yur].

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, denoted Co_4Al_{13}(o), Co_4Al_{13}(m), and Z, respectively by [2002Yur]), and Co_2Al_9 ($D8_d$-type monoclinic). The Al-Pd phase diagram [2001Yur] depicts the following intermediate phases: $PdAl_4$ (hexagonal, space group $P6_322$), $PdAl_3$ (denoted ε_6, orthorhombic), ε_{28} ($\sim PdAl_3$, orthorhombic), Pd_8Al_{21} (Pt_8Al_{21}-type tetragonal), Pd_2Al_3 (denoted δ, $D5_{13}$, Ni_2Al_3-type hexagonal), PdAl (*B*2-type cubic and two low-temperature forms: rhombohedral and *B*20-type cubic), Pd_5Al_3 (Rh_5Ge_3-type orthorhombic), Pd_2Al(*C*23, Co_2Si-type orthorhombic), and Pd_5Al_2 (Pd_5Ga_2-type orthorhombic). In the Co-Pd system, Co and Pd form a continuous face-centered cubic (fcc) solid solution.

The Ternary Phase Equilibria

The structural characteristics of six stable ternary phases of this system were summarized by [2002Yur], see Table 1. Following [2002Yur], these are denoted using the symbols W, V, U, F, C_2, and Y_2. In addition, the ε-family of orthorhombic phases ε_{22} and ε_{34} were identified by [2002Yur] in the ternary region, Table 1. All ε-type phases are clubbed together and labeled ε in the isothermal sections drawn by [2002Yur].

With starting metals of 99.9999% Al, 99.95% Co, and 99.95% Pd, [2002Yur] levitation-melted 90 Al-rich ternary alloys. The alloys were annealed at 1050-790 °C for 100-2050 h. The phase equilibria were studied by x-ray powder diffraction and scanning electron microscopy. Local phase compositions were measured with energy dispersive x-ray analysis and inductively-coupled plasma optical emission

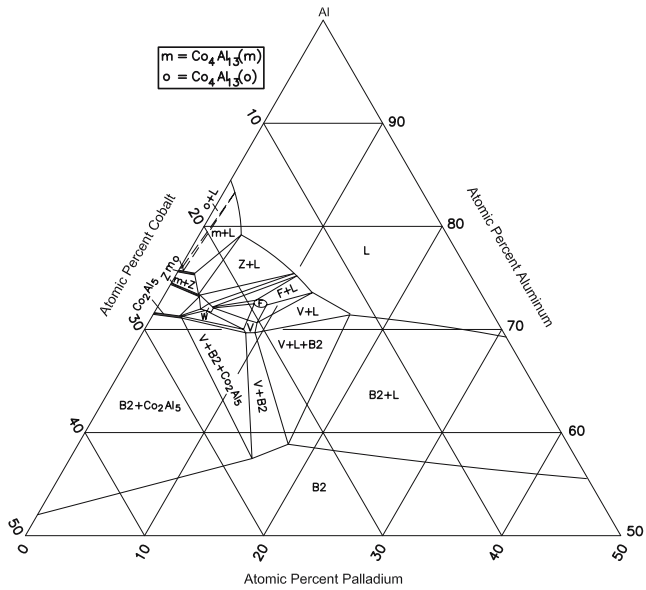

Fig. 1 Al-Co-Pd isothermal section at 1050 °C [2002Yur]

Table 1 Al-Co-Pd Crystal Structure and Lattice Parame-ter Data [2002Yur]

Phase designation	Composition, at.%	Space group	Lattice parameter, nm			
			a	*b*	*c*	β(°)
W	72.0 Al 23.2 Co 4.8 Pd	$Pmn2_1$	2.36	0.82	2.07	...
V	70.0 Al 20.0 Co 10.0 Pd	*P*121, *P*1*m*1 or *P*12/*m*1	1.0068	0.3755	0.6512	102.38
U	69.1 Al 14.4 Co 16.5 Pd	*C*121, *C*1*m*1 or *C*12/*m*1	1.9024	2.9000	1.3140	117.26
F	72.8 Al 18.2 Co 9.0 Pd	$P2_1/a\bar{3}$	2.4397	...	...	...
C_2	63.0 Al 10.5 Co 26.5 Pd	$Fm\bar{3}$	1.5507	...	...	...
Y_2	75.5 Al 20.7 Co 3.8 Pd	*Immm*	1.5451	1.2105	0.7590	...
ε_{22}	72.0 Al 8.0 Co 20.0 Pd	(a)	2.35	1.68	5.70	...
ε_{34}	70.0 Al 15.0 Co 15.0 Pd	(a)	2.35	1.68	7.01	...

(a) Orthorhombic

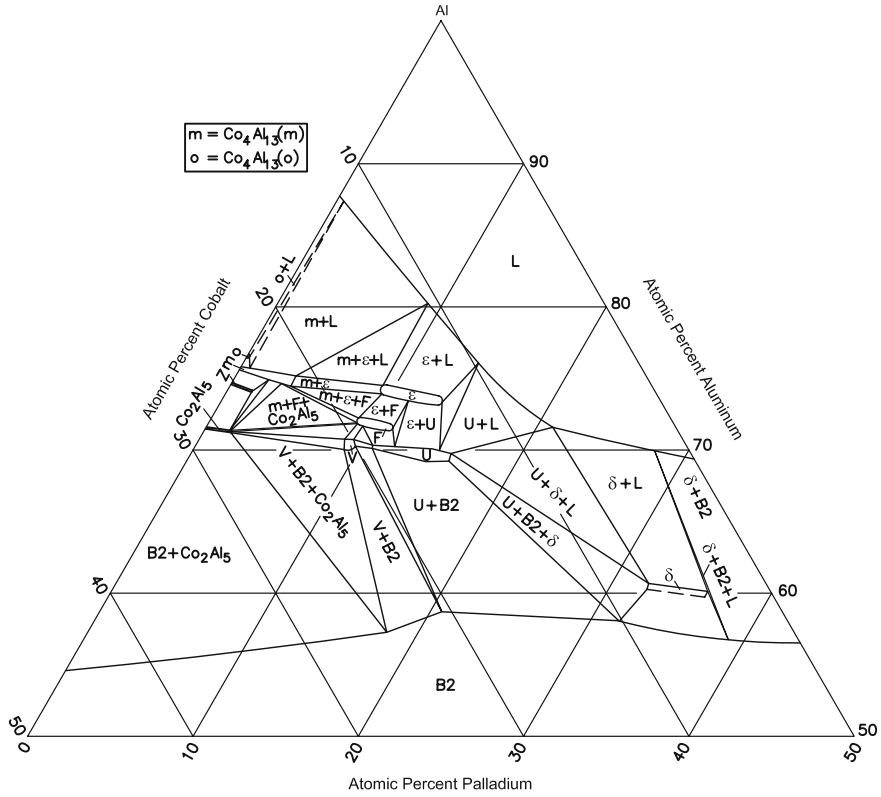

Fig. 2 Al-Co-Pd isothermal section at 1000 °C [2002Yur]

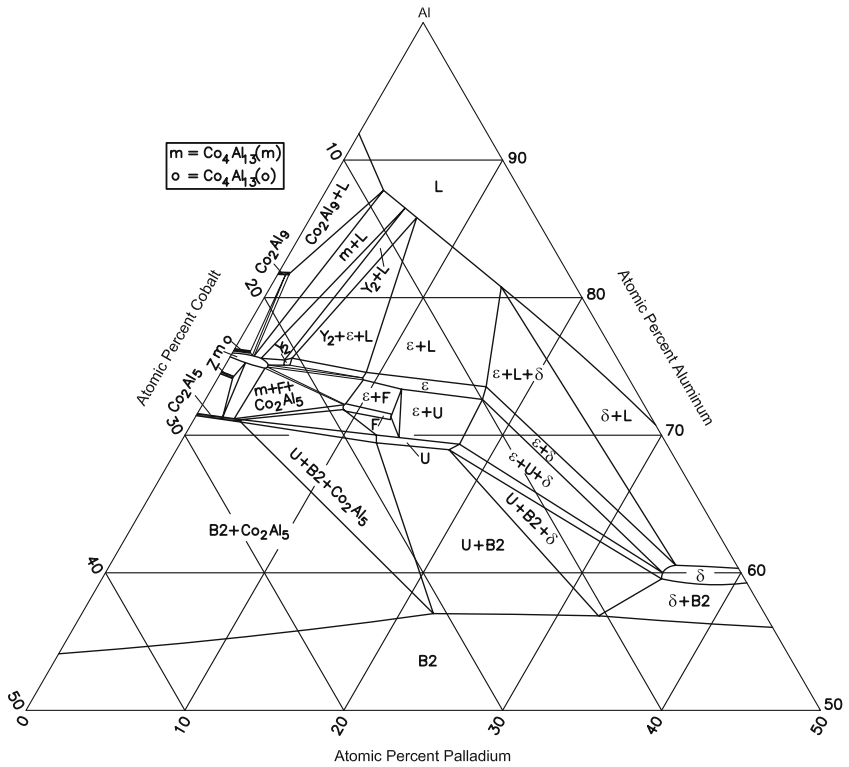

Fig. 3 Al-Co-Pd isothermal section at 940 °C [2002Yur]

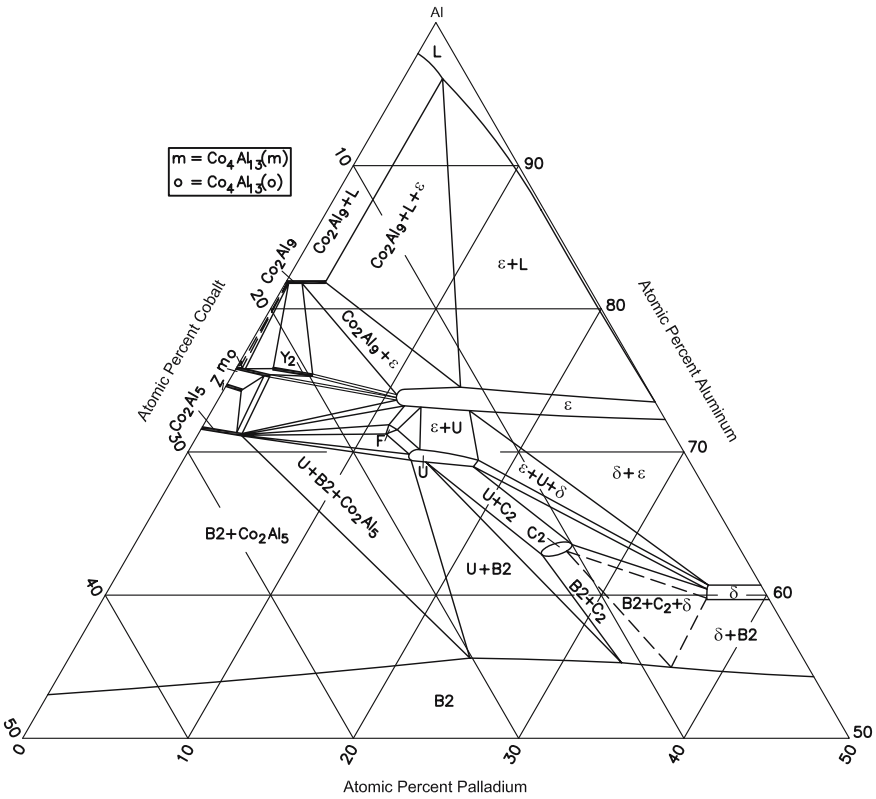

Fig. 4 Al-Co-Pd isothermal section at 790 °C [2002Yur]

spectroscopy. Four partial isothermal sections were constructed in the Al-rich region at 1050, 1000, 940, and 790 °C, as shown in Fig. 1-4.

At 1050 °C (Fig. 1), CoAl and PdAl form a continuous *B*2 solid solution. The maximum solubility of Al in *B*2 is 58.5 at.% and occurs at 18 at.% Pd. The solubility of Pd in Co_2Al_5, Co_4Al_{13}(m) and Z phases is 3.0, 2.7, and 3.4 at.%, respectively. The ternary phases F, V, and W are present and form tie-lines with the liquid. The W phase has a small homogeneity range around the composition $Al_{72.5}Pd_4Co_{23.5}$. The Pd content of the F phase is 9.4-8.2 at.% at approximately constant Al content. The V phase has a composition range of $Al_{69.7}Pd_{9.5}Co_{20.8}$-$Al_{71}Pd_{8.6}Co_{20.4}$. The binary phases Co_2Al_9 and Pd_2Al_3 are not stable at this temperature.

At 1000 °C (Fig. 2), the Al solubility in *B*2 remains the same as at 1050 °C. The solubility of Pd in Co_2Al_5, Co_4Al_{13}(m) and Z phases is 3.1, 3.8, and 2.5 at.%, respectively. The binary phase Pd_2Al_3 (denoted δ) nucleates in the ternary region and is stable between 7.1 and 3.8 at.% Co. The ε phase has a range of 73.2-74.6 at.% Al and 9.6-14 at.% Pd. Among the ternary phases, W is not present, having decomposed between 1050 and 1000 ° C. The F phase has a range of 71.3-72.2 at.% Al and 9.4-12.5 at.% Pd. The V phase has a range of 70.1-71 at.% Al and 8.5-9.8 at.% Pd. Both F and V are no longer in equilibrium with the liquid. The U phase has formed, with a range of 69.4-70.4 at.% Al and 11.3-16.9 at.% Co.

At 940 °C (Fig. 3), the binary phase Co_2Al_9 is additionally present. The Pd_2Al_3 (δ) has spread to the Al-Pd side. The solubility of Pd in Co_2Al_9, Co_4Al_{13}(o), Co_4Al_{13}(m), Z, and Co_2Al_5 is 0.9, 1.2, 2.7, 1.6, and 3.0 at.%, respectively. The ternary phase V is unstable. The Y_2 phase has become stable around the composition $Al_{74.8}Pd_{3.8}Co_{21.4}$. The F phase has a range of 8.7-12.4 at.% Pd and 72-72.5 at.% Al. At 790 °C (Fig. 4), the C_2 phase has appeared as an additional ternary phase. The measured compositions of the phases in the three-phase equilibria at each of the above temperatures were listed by [2002Yur].

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