Aluminium – Cobalt – Hafnium

Ortrud Kubaschewski, updated by Lazar Rokhlin, Nataliya Bochvar

Literature Data

The present evaluation of the Al-Co-Hf system incorporates and updates the assessment made by [1991Kub] in the MSIT Evaluation Program, based on data published by [1965Mar, 1969Mar, 1971Bur, 1974Dwi, 1974Mar, 1974Zie]. In all the works crystal structure of the ternary compounds have been studied, and [1971Bur] in addition investigated the phase equilibria in the area Al-$HfAl_2$-$HfCo_2$-Co.
Further reviews by [1977Abr, 1990Kum] do not really add to the published knowledge, as they merely describe the Al-Co-Hf phase diagram as presented by [1971Bur] not addressing the inconsistencies with later data.
In addition to the above investigations of the Heusler phase $HfCo_2Al$ published by [1983Bus] are to be considered, in particular as their measurements of the lattice parameters in $HfCo_2Al$ turned out to be close to those by [1965Mar, 1974Zie]]. The match of the ternary and the edge binary phases needs to be reviewed, as new critical evaluations of the Al-Co and Co-Hf systems have superseded the binary phase diagrams published earlier.

Binary Systems

The phase diagram of Al-Hf published in [1981Kub] still reflects the present state of knowledge, whereas revised binary phase diagrams are available from the MSIT Binary Evaluation Program for Al-Co [2003Gru] and for Co-Hf [2003Rok]. [2003Gru] shows three different compounds to exist in the vicinity of Co_4Al_{13} which earlier was considered to be the only compound. The three compounds shown by [2003Gru] are O-Co_4Al_{13}, M-Co_4Al_{13} and Y. The first one is stable down to room temperature, the two others exist only at higher temperatures. According to [2003Gru] a monoclinic phase designated Z exists in the vicinity of the composition $CoAl_3$.

Solid Phases

Nine ternary phases were found to exist in the Al-Co-Hf system [1991Kub]. These are $HfCoAl_4$, $Hf_6Co_7Al_{16}$, $HfCo_2Al$, Hf_6CoAl_2, λ_1, λ_2, X, H' and L'. The λ_1, λ_2 phases show pronounced ranges of homogeneity along the section for $HfAl_2$-$HfCo_2$. The λ_1 phase includes the composition HfCoAl and is limited in its homogeneity range by the concentrations 33.3Hf-(16.7-49.7)Co(18-50)Al (at.%). The range of λ_2 - is significantly less than that of λ_1 and limited by the concentrations 33.3Hf-(9.7-6.7)Co(57-60)Al (at.%). Compositions of X, H', L' were established by X-ray measurements and metallographic observations without determination of their crystal structures. [1971Bur] supposes that the homogeneity range of the compound $HfCo_2$ expands into the ternary system, up to 10 at.% Al. Crystal structures of the solid phases are presented in Table 1 with unary and binary phases pertinent to the isothermal section at 800°C.

Isothermal Sections

From the data reported by [1971Bur] and the data from the recently evaluated Al-Co and Co-Hf systems an amended partial isothermal section can be drawn, in the limits of the area Al-$HfAl_2$-$HfCo_2$-Co. In accordance with the binary Co-Hf phase diagram the phase Hf_6Co_{23} is stable in the temperature range 1270-950°C and, therefore, is removed from the isothermal section at 800°C [1971Bur]. The phase Hf_2Co_7, however, is stable at 800°C and, therefore inserted in the isothermal section. Corrections according to the accepted binary Al-Co system include replacement of the phases Co_4Al_{13} and $CoAl_3$ with the phases O-Co_4Al_{13} and Z, respectively.
For a number of other solid phases the range of existence is not firmly established. By lack of information these phases appear in Fig. 1 as points only, subject to future research.

Notes on Materials Properties and Applications

After annealing at 1000°C for 3 days [1983Bus] found that the Heusler phase $HfCo_2Al$ exhibits magnetic properties with a Curie temperature of 193 K and a saturation magnetic moment of 0.82 at 4.2 K.

Miscellaneous

[1987Kis] successfully applied computer forecasting to retrospectively predict the existence of the Heusler phase $HfCo_2Al$ from semi-empirical and fundamental data.

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Table 1: Crystallographic Data of Solid Phases

Phase/ Temperature Range [°C]	Pearson Symbol/ Space Group/ Prototype	Lattice Parameters [pm]	Comments/References
(Al) < 660.452	*cF*4 *Fm*$\bar{3}$*m* Cu	*a* = 404.88	pure Al [2003Gru] dissolves up to 0.186 at.% Hf at 662.2°C and 0.5 at.% Co at 657°C [Mas2]
(αCo) 1495-422	*cF*4 *Fm*$\bar{3}$*m* Cu	*a* = 354.46	dissolves up to 19.5 at.% Al at 1400°C [Mas2] and 0.8 at.% Hf at 1100°C [2003Rok]
(ϵCo) < 422	*hP*2 *P6*$_3$*/mmc* Mg	*a* = 250.71 *c* = 406.86	[Mas2, 2003Rok]
Co_2Al_9 < 970	*mP*22 *P2*$_1$*/a* -	*a* = 855.6 *b* = 629.0 *c* = 621.3 β = 94.76°	[V-C2, 2003Gru]
O-Co_4Al_{13} <1080	*oP*102 *Pmn2*$_1$ O-Co_4Al_{13}	*a* = 815.8 *b* = 1234.7 *c* = 1445.2	[2003Gru]
M-Co_4Al_{13} 1093-?	*mC*102 *C2/m* Fe_4Al_{13}	*a* = 1517.3 *b* = 810.9 *c* = 1234.9 β = 107.84°	[2003Gru]
Y 1124-?	*oI** *Immm* - *mC*34 *C2/m* Os_4Al_{13}	*a* = 1531.0 *b* = 1235.0 *c* = 758.0 *a* = 1704.0 *b* = 409.0 *c* = 758.0 β = 116.0°	[2003Gru]
Z < 1158	C-centr. monocl.	*a* = 3984.0 *b* = 814.8 *c* = 3223.0 β = 107.97°	[2003Gru]
Co_2Al_5 < 1188	*hP*28 *P6*$_3$*/mmc* Co_2Al_5	*a* = 767.2 *c* = 760.5 *a* = 767.15 *c* = 760.85	[2003Gru] [V-C2]

Phase/ Temperature Range [°C]	Pearson Symbol/ Space Group/ Prototype	Lattice Parameters [pm]	Comments/References
$Co_{1-x}Al_x$ < 1640	*cP*2 $Pm\bar{3}m$ CsCl	*a* = 285.7 *a* = 286.2 *a* = 285.9 *a* = 286.11	at *x* = 0.52 [2003Gru] at *x* = 0.5 [2003Gru] at *x* = 0.43 [2003Gru] [V-C2]
$\beta HfAl_3$ ~1590-~650	*tI*16 *I4/mmm* $ZrAl_3$	*a* = 389 to 401 *c* = 1714 to 1731	[1981Fer]
$\alpha HfAl_3$ ≲ 650	*tI*8 *I4/mmm* $TiAl_3$	*a* = 389 to 393 *c* = 893 to 889	[1981Fer]
$HfAl_2$ < 1650	*hP*12 $P6_3/mmc$ $MgZn_2$	*a* = 523 to 529 *c* = 865 to 874	[1981Fer]
$HfCo_7$ 1255-1050	*tP*32 - -	*a* = 707.0 *c* = 799.9	at 12.5 at. % Hf [2003Rok, 1981Fer]
Hf_6Co_{23} 1275-950	*cF*116 $Fm\bar{3}m$ $Mn_{23}Th_6$	*a* = 1148.0 *a* = 1150.2	at 20.7 at.% Hf [2003Rok] at 1200°C (annealed) [1981Fer]
Hf_2Co_7 < 1350	*o*** - (Ni_7Zr_2)	*a* = 444.4 *b* = 819.1 *c* = 1214.0	at 22.2 at.% Hf [2003Rok, 1981Fer]
$HfCo_2$ < 1670	*cF*24 $Fd\bar{3}m$ Cu_2Mg	 *a* = 689.8 to 692.2 *a* = 691.2 to 692.2	from at least 28 up to 35 at.% Hf [2003Rok] [2003Roc] [1981Fer]
* $HfCo_2Al$	*cF*16 $AlCu_2Mn$	*a* = 601.9 *a* = 600.9 *a* = 604.5	(+some $CoHf_2$) [1974Zie] [1965Mar] [1983Bus]
* ~$Hf_6Co_7Al_{16}$	*cF*116 $Fm\bar{3}m$ Th_6Mn_{23}	*a* = 1206	[1969Mar]
* ~$HfCoAl_4$	- - ($ZrCoAl_4$)	*a* = 718 *c* = 895	[1969Mar]
* Hf_6CoAl_2	*hP*9 $P6\bar{2}m$ Zr_6CoAl_2	*a* = 781 *c* = 328	[1969Mar, 1971Bur]
* λ_1, $Hf(Co_{1-x}Al_x)_2$	*hP*12 $P6_3/mmc$ $MgZn_2$	*a* = 503 to 518 *c* = 806 to 848 *a* = 508.1 *c* = 819.1 *a* = 506 *c* = 802	at 0.25≤ *x* ≤0.75 [1971Bur] for HfCoAl [1974Dwi] for HfCoAl [1974Mar]

Phase/ Temperature Range [°C]	Pearson Symbol/ Space Group/ Prototype	Lattice Parameters [pm]	Comments/References
* λ_2, $Hf(Co_xAl_{1-x})_2$	*cF*24 $Fd\bar{3}m$ $MgCu_2$	a = 737.5	$0.10 \leq x \leq 0.15$ [1971Bur] at x = 0.15 [1971Bur]
* L' $Hf_{20}Co_{70}Al_{10}$	not determined		[1971Bur]
* X $Hf_4Co_{22}Al_{74}$	not determined		[1971Bur]
* H' $Hf_{30}Co_{52}Al_{18}$	not determined		[1971Bur]

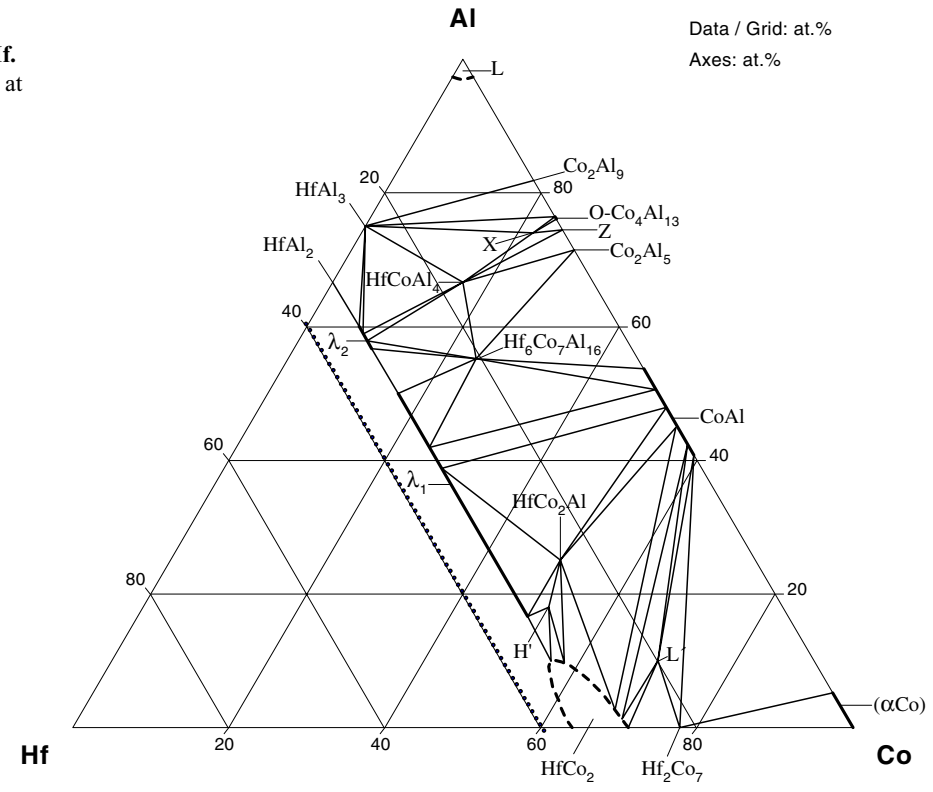

Fig. 1: Al-Co-Hf. Isothermal section at 800°C