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Al-C-Ti (Aluminum-Carbon-Titanium)

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The review of this system by [1990Hay] presented three isothermal sections at 1250, 1000, and 750 °C (with two ternary compounds *P* and *H*) and vertical sections at 2, 4, 6, 8, and 10 wt.% Al. Recent results include an isothermal section at 1300 °C by [1994Pie] (depicting a new ternary compound labeled *N*) and a thermodynamic analysis of [1998Fra] of Al-rich alloys, which takes into account the nonstoichiometry of titanium monocarbide.

Binary Systems

The Al-rich part of Al-C phase diagram [1991Har] shows that the only intermediate phase in the system is Al_4C_3 ($D7_1$-type rhombohedral) and is formed through a peritectic reaction at 2173 °C between graphite and liquid containing 18.6 at.% C. The updated version of the Al-Ti phase diagram [2005Rag] depicts a number of intermediate phases: $TiAl_3$ ($D0_{22}$-type tetragonal), Ti_5Al_{11} (tetragonal), $TiAl_2$ ($HfGa_2$-type tetragonal), $Ti_{1-x}Al_{1+x}$ (AuCu-type tetragonal), Ti_3Al_5 (tetragonal), TiAl (γ) (AuCu-type tetragonal) and Ti_3Al (α_2) ($D0_{19}$, Ni_3Sn-type hexagonal). In the Ti-C phase diagram [1996Sei], TiC_{1-x} ($x = 0.02$ to 0.52) is a NaCl-type cubic structure. For a recent thermodynamic description of the Ti-C system, see [2003Fri].

Ternary Compounds

Three ternary compounds are known in this system. Ti_3AlC_{1-x} (denoted *P*) has the $E2_1$, perovskite-type cubic structure. Ti_2AlC_{1-x} (denoted *H*) has the Cr_2AlC-type hexagonal structure [Pearson3]. Ti_3AlC_{2-x} (denoted *N*) with the Ti_3SiC_2-type hexagonal structure was reported by [1994Pie] at 1300 °C. It is not present in the isothermal section at 1250 °C [1990Hay] and appears to be a high-temperature phase stable in a narrow temperature range. The crystal structure data on the above compounds are listed in Table 1.

Liquid-Solid Equilibria

The liquid-solid equilibria have been studied in Al-rich alloys of this system [1990Via, 1993Jar, 1993Sve, 1995Wan, 1998Fra]. The thermodynamic analysis of [1998Fra] takes into account the variation in stoichiometry of TiC_{1-x}. On this basis, the equilibrium near the Al corner at 1027 °C calculated by [1998Fra] is redrawn in Fig. 1. Due to the very small concentration of C in the Al-rich liquid (denoted L_{Al}), the C axis is on a logarithmic scale. The location of TiC_{1-x} is schematic and is not drawn to scale. The stoichiometric variation of TiC_{1-x} in equilibrium with the liquid is shown by the tie-lines in Fig. 1. At Ti < 0.37 at.%, liquid Al is in equilibrium with Al_4C_3. Between Ti of 0.37-5.25 at.%, the two-phase equilibrium (L_{Al} + TiC_{1-x}) prevails. At Ti > 5.25 at.%, the liquid is in equilibrium with $TiAl_3$.

The computed liquidus projection of [1998Fra] near the Al corner is shown in Fig. 2. The constant-temperature contour lines are indicated. In the (L_{Al} + TiC_{1-x}) two-phase region, the variation of x in TiC_{1-x} is indicated on the contour lines. The liquidus lines corresponding to the (L_{Al} + Al_4C_3 + TiC_{1-x}) and (L_{Al} + TiC_{1-x} + $TiAl_3$) three-phase equilibria meet on an invariant plane at 693 °C, where the U reaction occurs: $L_{Al} + TiC_{1-x} \leftrightarrow Al_4C_3 + TiAl_3$ [1990Via, 1993Sve, 1998Fra], with the liquid composition of $C = 7 \times 10^{-6}$ at.% and Ti = 0.53 at.% [1998Fra]. Below 693 °C, the liquid does not form tie-lines with TiC_{1-x}. A liquidus projection for Al-rich alloys was presented by [1990Via]. A schematic projection for the entire composition range was given by [1994Pie].

Isothermal Sections

A number of isothermal sections have been reported for this system: [1990Via] (827 and 727 °C), [1991Cam] (partial at 1250, 1050, and 750 °C), [1994Pie] (1300 and 1000 °C), [1994Zha] (1100 °C), and [2000Ban] (reviewed

Table 1 Al-C-Ti crystal structure and lattice parameter data

Phase	Composition, at.%	Pearson symbol	Space group	Prototype	Lattice parameter, nm
$Ti_3AlC_{0.58}$ (*P*)	21.8 Al	*cP*5	$Pm\bar{3}m$	$CaTiO_3$	$a = 0.4156$
	12.7 C				
	65.5 Ti				
$Ti_2AlC_{0.69}$ (*H*)	27.1 Al	*hP*8	$P6_3/mmc$	Cr_2AlC	$a = 0.3056$
	18.7 C				$c = 1.3623$
	54.2 Ti				
$Ti_3AlC_{1.9}$ (*N*)	16.95 Al	*hP*12	$P6_3/mmc$	Ti_3SiC_2	$a = 0.3075$
	32.2 C				$c = 1.8578$
	50.85 Ti				

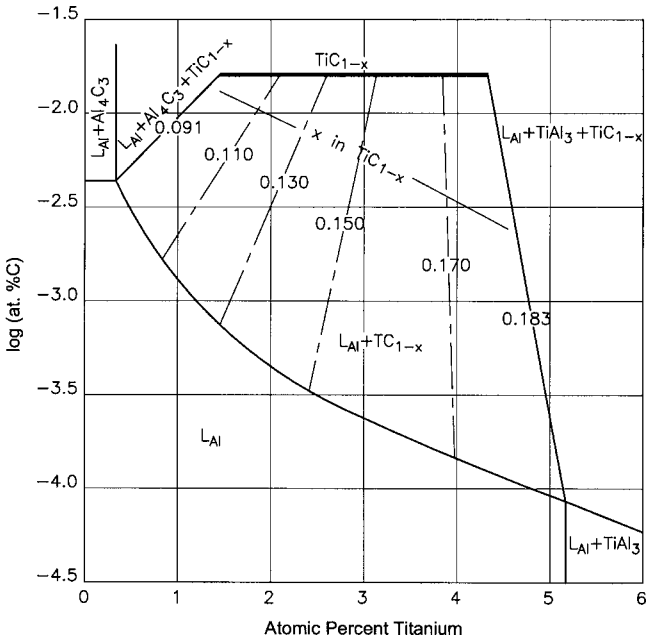

Fig. 1 Al-C-Ti computed isothermal section at 1027 °C. The location and range of TiC_{1-x} are not drawn to scale [1998Fra]

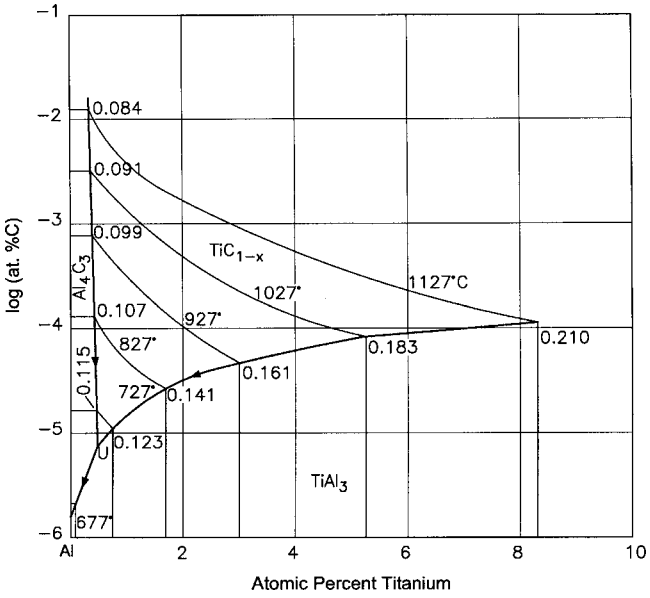

Fig. 2 Al-C-Ti computed liquidus projection. The fractional numbers are x values in TiC_{1-x} [1998Fra]

sections at 1300, 1100, and 1000 °C). The ternary phases Ti_3AlC_{1-x} (*P*) and Ti_2AlC_{1-x} (*H*) are present at all temperatures between 1300 and 750 °C. The third ternary phase Ti_3AlC_{2-x} (*N*) was reported only at 1300 °C [1994Pie]. The reviewed isothermal sections of [2000Ban] are readily modified to agree with the binary data accepted here. A reaction scheme has been proposed for this system by [1994Pie].

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