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# Al-C-N-Ti (Aluminum-Carbon-Nitrogen-Titanium)

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[1996Pie] investigated the phase relationships in this quaternary system and presented a vertical section along the $Ti_3AlC_{1-x}$-$Ti_3AlN_{1-x}$ join and a schematic table of the interrelationships between the tie-tetrahedra and the adjoining three-phase fields of the system.

## Binary Systems

For brief descriptions of the Al-C, Al-Ti, and C-Ti phase diagrams, see the Al-C-Ti update in this issue. The Al-N-Ti update gives descriptions of the Al-N and N-Ti diagrams.

## Ternary Systems

The Al-C-N, Al-C-Ti, and Al-N-Ti ternary systems are updated in this issue.

[1996Jon] made a thermodynamic assessment of the C-N-Ti system and presented a computed liquidus surface and isothermal sections for the Ti-TiC-TiN region at 1820, 1650, 1150, and 500 °C. Comparison with the available experimental data from the literature showed reasonable agreement with the computed isothermal sections. Recently, [2004Fri] obtained new experimental results and presented a revised thermodynamic description of the C-N-Ti system. Of the three isothermal sections computed by [2004Fri] at 1650, 1150, and 500 °C, the section at 1150 °C is redrawn in Fig. 1. The monocarbides $TiC_{1-x}$ and $TiN_{1-x}$ form a continuous series of solid solutions at all the three temperatures.

## Quaternary Phase Equilibria

With starting materials of 99.0% Ti, 99.8% Al, TiAl, TiC, TiN, AlN, $Al_4C_3$, and graphite powders, [1996Pie] prepared about 9 quaternary alloys with Ti up to 50 at.%, by powder compacting and sintering at 1375 °C for 20 h. The phase equilibria were studied by x-ray powder diffraction. The melting temperatures were determined by optical pyrometry.

In the composition range studied, the following four-phase spaces were identified: (Al) + Ti(C,N) + AlN + $Al_4C_3$, (Al) + Ti(C,N) + AlN + $TiAl_3$, $TiAl_3$ + $Ti_5Al_{11}$ +

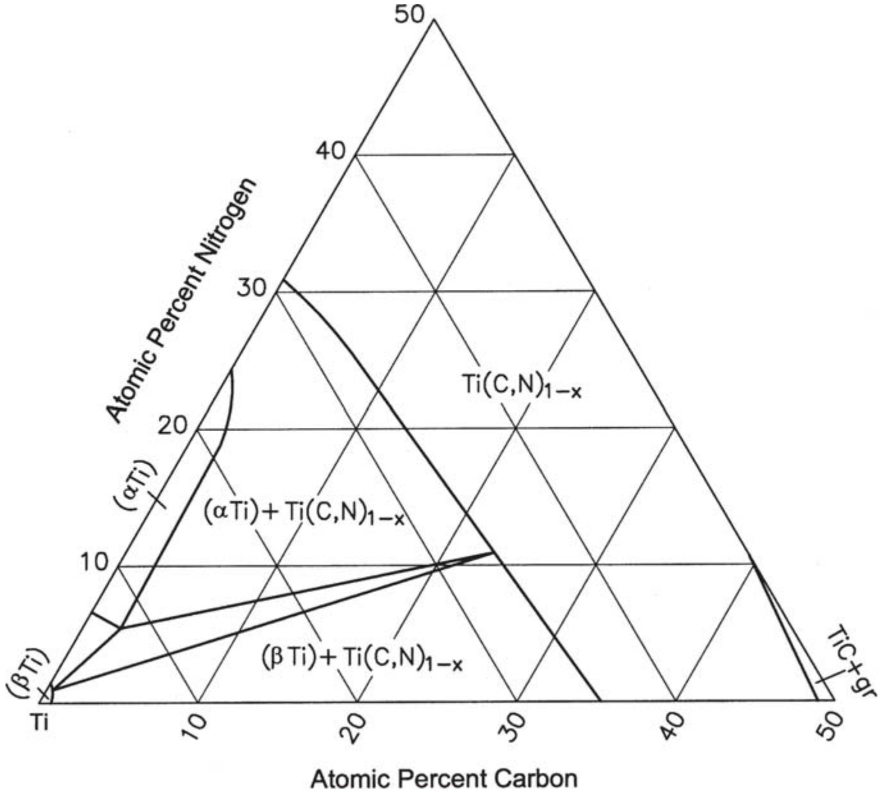

**Fig. 1** C-N-Ti computed isothermal section at 1150 °C [2004Fri]

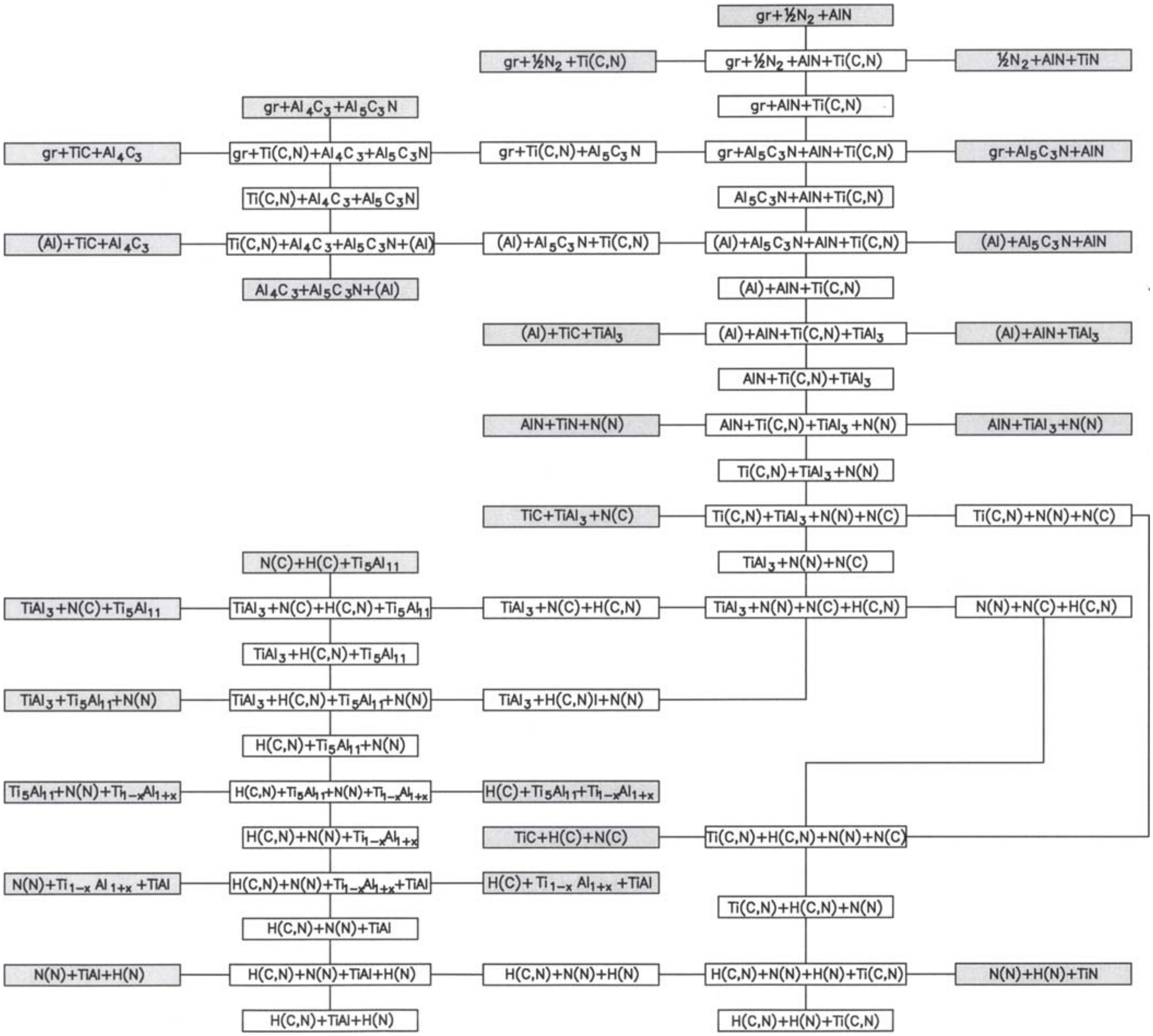

**Fig. 2** Al-C-N-Ti network of three-phase and four-phase spaces at 1375 °C [1996Pie]

*N*(C) + *H*(C,N), and Ti(C,N) + *N*(N) + *N*(C) + *H*(C,N). In the above, *N*(C) = $Ti_3AlC_2$, *N*(N) = $Ti_4AlN_{3-x}$, *H*(C) = $Ti_2AlC$, and *H*(N) = $Ti_2AlN$. *H*(C,N) denotes the continuous solid solution between *H*(C) and *H*(N) at 1495 °C and the *H*(C)-based solid solution with an extended homogeneity range at 1375 °C. *H*(N), *N*(N), and *N*(C) do not show any significant fourth-component solubility at 1375 °C. A tentative network of three-phase and four-phase spaces for the composition region studied at 1375 °C was proposed by [1996Pie]. This is shown in Fig. 2 after correction of one or two misprints. The ternary isothermal sections used by [1996Pie] are: Al-C-Ti (1300 °C), Al-C-N (1500 °C), Al-N-Ti (1300 °C), and C-N-Ti (1150 °C).

A four-phase space is a tie-tetrahedron. It is surrounded by four three-phase spaces butting against the four faces of the tie-tetrahedron. The three-phase spaces that lie entirely within the composition tetrahedron are usually common to two adjacent tie-tetrahedra. The three-phase spaces originating from the ternary systems are shaded gray in Fig. 2. Each one of these butts against only one tie-tetrahedron. The two three-phase spaces at the end of the table *H*(C,N) + γ-TiAl + *H*(N) and *H*(C,N) + *H*(N) + Ti(C,N) lie entirely within the composition tetrahedron. Their links to other phase-spaces probably lie outside the composition range studied by [1996Pie].

Along the *H*(C)-*H*(N) join, complete solid solubility exists at 1495 °C. [1996Pie] found that the unit cell volume of this solid solution varies nonlinearly along this join. At 1375 °C, a miscibility gap arises. The compositions of the two coexisting phases at this temperature were estimated by

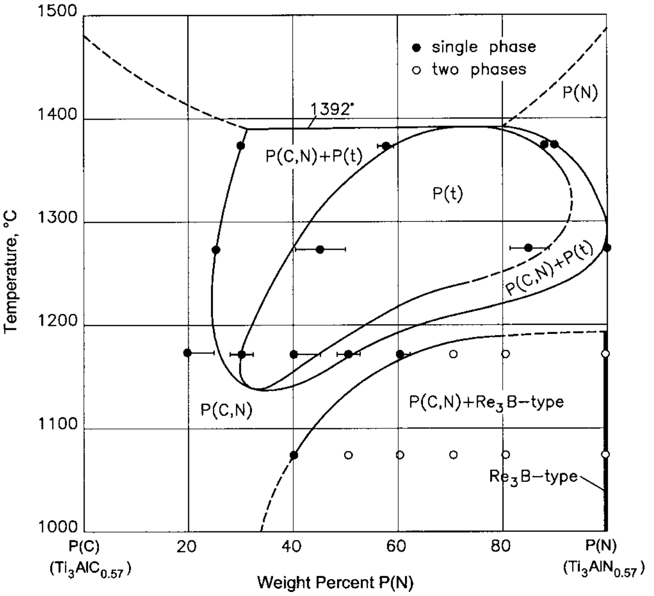

**Fig. 3** Al-C-N-Ti vertical section along the *P*(C)-*P*(N) join [1996Pie]

[1996Pie] to be $Ti_2Al(C_{0.3}N_{0.7})_{0.75}$ and $Ti_2AlN_{0.8}$, respectively.

Along the $Ti_3AlC_{1-x}$ [denoted *P*(C)]-$Ti_3AlN_{1-x}$ [denoted *P*(N)] join, the isostructural perovskite-type phases do not dissolve in each other at the highest temperature investigated (1495 °C) [1996Pie]. However, they show significant mutual solubility at lower temperatures. A tetragonally-distorted, perovskite-based structure denoted *P*(t) intervenes at lower temperatures. The vertical section along this join proposed by [1996Pie] is shown in Fig. 3. *P*(t) appears to form through a peritectoid reaction at 1392 °C and transforms congruently at ~1140 °C to the *P*(C)-based solid solution. The measured lattice parameters of *P*(t) are $a = 0.41047$ to 0.41155 nm and $c = 0.41348$ to 0.41354 nm in the composition range of 12-25 wt.% *P*(C) and 88-75 wt.% *P*(N) [1996Pie]. Below 1200 °C, the $Re_3B$-type orthorhombic phase, which is the low-temperature modification of $Ti_3AlN_{1-x}$, is present and shows no solubility for carbon.

## References

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