Ternary Alloys

A Comprehensive Compendium of Evaluated Constitutional Data and Phase Diagrams

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Aluminium – Carbon – Niobium

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Introduction

Alloys of refractory carbides with low-melting semi-metals (Al) produced by powder metallurgical methods were investigated by [63Jei1], [63Jei2] and [64Now]. They found, using powder X-ray methods, a ternary phase Nb_3Al_2C and called it H-phase.
Using microscopic and X-ray analysis, measurements of T_c and certain other properties [79Sav], [81Sav] and [83Sav] established that in the Al-C-Nb system, at 800 °C, the lower carbide of Nb is in equilibrium with compounds of the A15 structural type. In Nb alloys containing up to 40 at.% Al and up to 30 at.% C no new ternary compounds were observed.
The phase diagrams for the ternary system Al-C-Nb were established by [80Sch] using arc melted samples, annealed at 700 and 1000 °C, examined by X-ray diffraction methods. They found the H-phase Nb_2AlC (The carbide Nb_3Al_2C is not stable at 700 to 1000 °C).
[80Pea] showed a dimensional analysis of a ternary phase satisfying the ratio of the radius of the metalloid to the radius of the transition metal valid for true Hägg interstitial phases.

Binary Systems

The Al-Nb system shows only three compounds, Nb_3Al, Nb_2Al and $NbAl_3$, with a solubility of 21.5 at.% Al in Nb at 2600 °C and less than 0.3 at.% Nb in Al at 661 °C. $NbAl_3$ melts congruently and Nb_3Al is formed peritectically; $NbAl_3$ has a very narrow homogeneity range [M] and [80Jor].
The Nb-C system [M and 87Smi] shows two compounds, NbC_{1-x} and stoichiometric Nb_2C. Below 1500 °C, the terminal solubility of carbon in Nb is quite small and reaches a maximum of only 5.7 at.% C at 2340 °C. The system includes a niobium-rich eutectic at 10.5 at.% and 2340 °C and a carbon-rich eutectic at 60 at.% C and 3300 °C. In the Al-C system [S], the phase Al_4C_3 is stable. A high temperature AlC phase [65Gin] could not be confirmed [87Ode].

Solid Phases

Two ternary phases are mentioned, Nb_3Al_2C and Nb_2AlC, both are H-phases. Only the latter is stable at elevated temperatures (700–1000 °C). The known phases are listed in Table 1.

Isothermal Sections

The isothermal section at 700 °C, Fig. 1, shows the H-phase Nb_2AlC in equilibrium with the Nb-aluminides and the Nb-carbides. There are no indications for a solubility of carbon in the aluminides. Also no solubility of aluminium in the Nb-carbides could be detected by X-ray methods. For the three-phase field $H + Nb_3Al + NbC_{1-x}$ the carbon concentration in the Nb-monocarbide was estimated to be 46 at.% C.
In the temperature range 700 to 1000 °C, the reaction $NbC_{1-x} + Al \rightleftarrows NbAl_3 + Al_4C_3$ takes place. The H-phase forming out of $NbAl_3 + NbC_{1-x}$ mixtures, the solid state reaction proceeds very slowly at 700 °C but at 1000 °C most of the H-phase has already formed after 170 h [80Sch].
In contradiction to [80Sch], [79Sav] reports the carbide Nb_2C to be in equilibrium with the α and σ phases, Nb_3Al, and NbC at 800 °C.

Miscellaneous

The effects of super-rapid quenching and subsequent annealing on the microstructure, phase composition and superconducting properties of Al-C-Nb alloys are:
As the cooling rate is increased a rapid decrease of the grain size is observed together with a gradual increase of the α phase content and a decrease of the content of other phases. The crystalline structure of the compounds disorders progressively. The composition of the A15 phases shifts towards the stoichiometric composition and the excess phases appear in initially two-phase alloys [84Sav].