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Al-Ce-Nd (Aluminum-Cerium-Neodymium)

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Recently, this system was investigated experimentally by [2003Car] and assessed thermodynamically by [2003Cac]. A computed isothermal section at 500 °C and a computed vertical section at a constant atom ratio of Ce/Nd = 1 are given in this review from the above studies.

Binary Systems

The Al-Ce phase diagram was recently reassessed thermodynamically by [2005Gao], using new experimental results as additional input. The intermediate phases in this system are: αCe_3Al ($D0_{19}$, Ni_3Sn-type hexagonal), βCe_3Al ($L1_2$, $AuCu_3$-type cubic), Ce_2Al (stable between 775 and 648 °C; Co_2Si-type orthorhombic?), CeAl (CeAl-type orthorhombic), $CeAl_2$ ($C15$, $MgCu_2$-type cubic), $\alpha CeAl_3$ (Ni_3Sn-type hexagonal), $\beta CeAl_3$ (stable between 1192 and 973 °C), $CeAl_4$ or βCe_3Al_{11} ($D1_3$, Al_4Ba-type tetragonal), and αCe_3Al_{11} (αLa_3Al_{11}-type orthorhombic). The Al-Nd phase diagram reassessed with new additional experimental input by [2005Gao] shows the following intermediate compounds: Nd_3Al ($D0_{19}$, Ni_3Sn-type hexagonal), Nd_2Al ($C23$, Co_2Si-type orthorhombic), NdAl (ErAl-type orthorhombic), $NdAl_2$ ($C15$, $MgCu_2$-type cubic), $\alpha NdAl_3$ (Ni_3Sn-type hexagonal), $\beta NdAl_3$ (stable between 1205 and 888 °C), $NdAl_4$ or βNd_3Al_{11} ($D1_3$, Al_4Ba-type tetragonal), and αNd_3Al_{11} (αLa_3Al_{11}-type orthorhombic). The Ce-Nd system has no intermediate phases.

Ternary Phase Equilibria

With starting metals of purity of 99.999% Al, 99.9% Ce, and 99.9 % Nd, [2003Car] induction-melted under Ar atm about 30 ternary alloys. The Al content of the alloys was in the range of 20-70 at.%. The samples were annealed at 500 °C for 1 week and quenched in water. To determine the liquidus temperatures, a few samples were subjected to differential thermal analysis at a heating/cooling rate of 10 °C per min. The phase equilibria were studied with metallography, electron probe microanalysis, and x-ray diffraction.

In the thermodynamic analysis of [2003Cac], the liquid phase, fcc, bcc, and αLa-type structures were described as substitutional solutions with a single lattice. The third component solubility in the binary compounds was

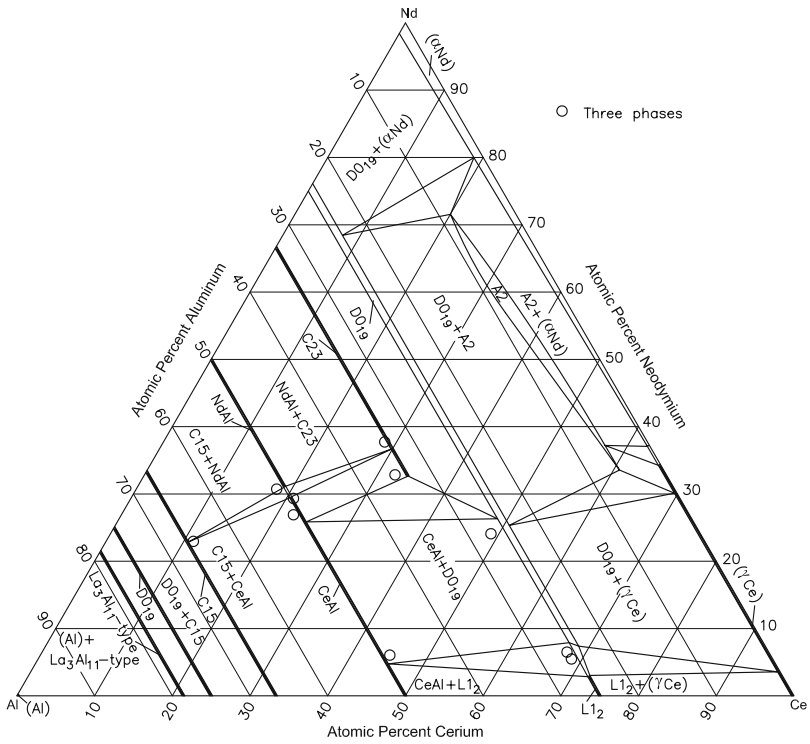

Fig. 1 Al-Ce-Nd computed isothermal section at 500 °C [2003Cac]

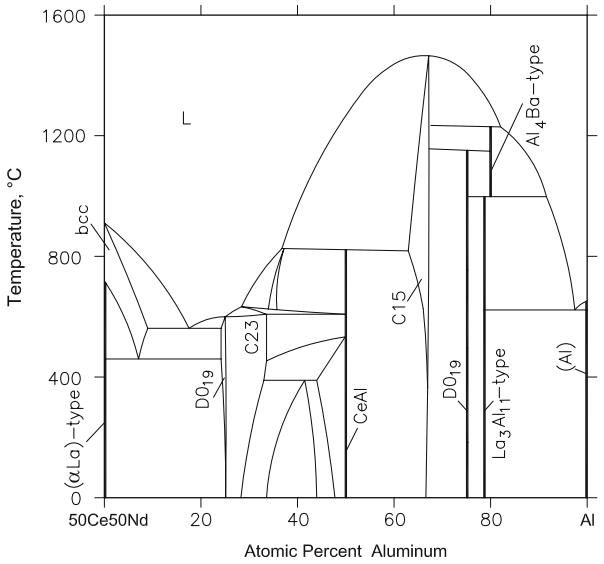

Fig. 2 Al-Ce-Nd computed vertical section at a constant atom ratio of Ce/Nd = 1 [2003Cac]

considered. The binary descriptions of Al-Ce and Al-Nd were taken from [2001Cac], with a reoptimization of the Al-Nd system. The Ce-Nd system was calculated by [2003Cac], assuming an ideal mixing in the liquid and solid phases. Using the experimental tie-lines and liquidus temperatures in the optimization, [2003Cac] computed a full isothermal section at 500 °C, which is shown in Fig. 1. The isomorphous pairs αCe_3Al_{11}-αNd_3Al_{11}, $\alpha CeAl_3$-$\alpha NdAl_3$, and $CeAl_2$-$NdAl_2$ form continuous solid solutions at 500 °C. In Fig.1, these are denoted as La_3Al_{11}-type, $D0_{19}$, and $C15$ respectively. A linear variation of the lattice parameter was found along the $CeAl_2$-$NdAl_2$ section by [2003Car]. This confirms the earlier result of [1985Ian]. The CeAl and NdAl show substantial mutual solid solubility, but there is no continuous solution, as the crystal structures are different. NdAl dissolves up to 19 at.% Ce and CeAl dissolves up to 29.5 at.% Nd. Nd_2Al and Nd_3Al dissolve about 34 and 68 at.% Ce respectively. Ce_3Al dissolves only 3 at.% Nd. Within the ternary region, a phase with the bcc ($A2$) structure is stable at an Al content of about 10 at.%. Noting that the high-temperature forms of Ce and Nd are bcc, we may conclude that Al stabilizes the bcc phase. Figure 2 shows a vertical section computed by [2003Cac] at a constant atom ratio of Ce/Nd = 1. Due to incomplete labeling of the phase fields by [2003Cac], the phase relations in the 30-50 at.% Al region are unclear. This section may be considered tentative, pending further experimental studies of the liquid-solid equilibria.

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