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Al-Pd-Re (Aluminum-Palladium-Rhenium)

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Recently, [2008Rag] briefly reviewed the results of [2004Bal] on this ternary system and gave their isothermal section at 1000 °C for Al-rich alloys. Very recently, [2008Bal] extended the results of [2004Bal], by adding three more isothermal sections at 1100, 790, and 700 °C.

Binary Systems

The Al-Pd phase diagram [2001Yur] shows the following intermediate phases: $PdAl_4$ (hexagonal, space group $P6_322$, denoted λ), $PdAl_3$ (denoted ε_6, orthorhombic), ε_{28} ($\sim PdAl_3$, orthorhombic), Pd_8Al_{21} (Pt_8Al_{21}-type tetragonal), Pd_2Al_3 (denoted δ, $D5_{13}$, Ni_2Al_3-type hexagonal), PdAl ($B2$, CsCl-type cubic and two low-temperature forms: rhombohedral and $B20$-type cubic), Pd_5Al_3 (Rh_5Ge_3-type orthorhombic), Pd_2Al ($C23$, Co_2Si-type orthorhombic), and Pd_5Al_2 (Pd_5Ga_2-type orthorhombic). The Al-Re system [2001Sch, 2008Bal] has the following intermediate phases: $ReAl_{12}$ (WAl_{12}-type cubic), $ReAl_6$ ($D2_h$, $MnAl_6$-type orthorhombic), $ReAl_4$ (HT) (high temperature phase stable above 1000 °C), Re_8Al_{33-x} or $ReAl_4$ (LT) (triclinic), $ReAl_3$ (23.4-25.2 at.% Re), Re_4Al_{11} (Mn_4Al_{11}-type triclinic), ReAl (CuTi-type tetragonal), and Re_2Al ($C11_b$, $MoSi_2$-type tetragonal). Additionally, [2004Bal] found a monoclinic phase $ReAl_3$, listed in [Massalski2]. The Pd-Re phase diagram is of the simple peritectic type.

Ternary Phases

Three ternary phases are known in this system: the icosahedral phase I, the decagonal phase D_6 and a hexagonal phase χ. The icosahedral phase I forms through a peritectic reaction at 1065 °C and has a compositional range from $Al_{71.9}Pd_{17.7}Re_{10.4}$ to $Al_{68.5}Pd_{22.8}Re_{8.7}$ at 1000 °C and from $Al_{71.6}Pd_{18.8}Re_{9.6}$ to $Al_{68.6}Pd_{23.1}Re_{8.3}$ at 800 °C. The D_6 phase has a composition of $\sim Al_{78.0}Pd_{7.8}Re_{14.2}$. A new phase χ of hexagonal structure was found to form peritectically at 842 °C, with a composition range from $Al_{77.8}Pd_{13.8}Re_{8.4}$ to $Al_{76.2}Pd_{19.0}Re_{4.8}$. It has the Ir_9Al_{28}-type hexagonal structure (space group $P31c$), with the lattice parameters $a = 1.2306$ nm and $c = 2.7417$ nm.

Isothermal Sections

Owing to the large difference in the melting points of the constituent metals, [2008Bal] initially prepared Al-Re and Al-Pd master alloys and then melted them with appropriate amounts of Al and Pd to prepare the ternary alloys of the desired composition. Induction melting under Ar atm was adopted. The alloys were annealed at 1100 °C for 21-47 h, at 1000 °C for 68-2181 h, at 790 °C for 627-2252 h, and at 700 °C for 4178 h. The phase equilibria were studied with optical,

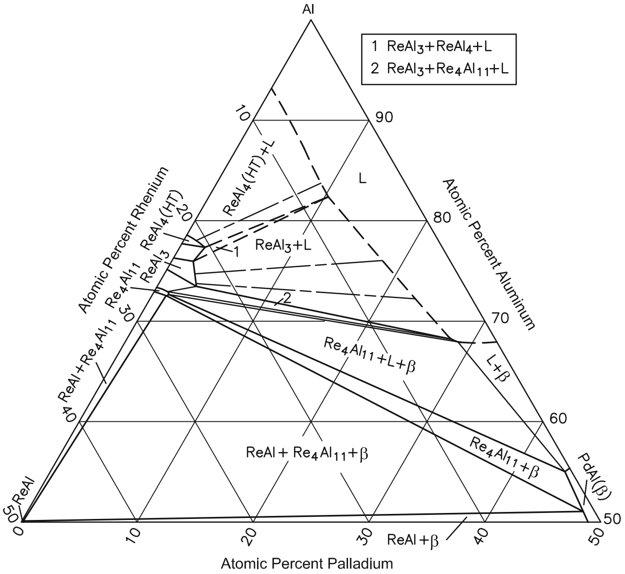

Fig. 1 Al-Pd-Re isothermal section for Al-rich alloys at 1100 °C [2008Bal]

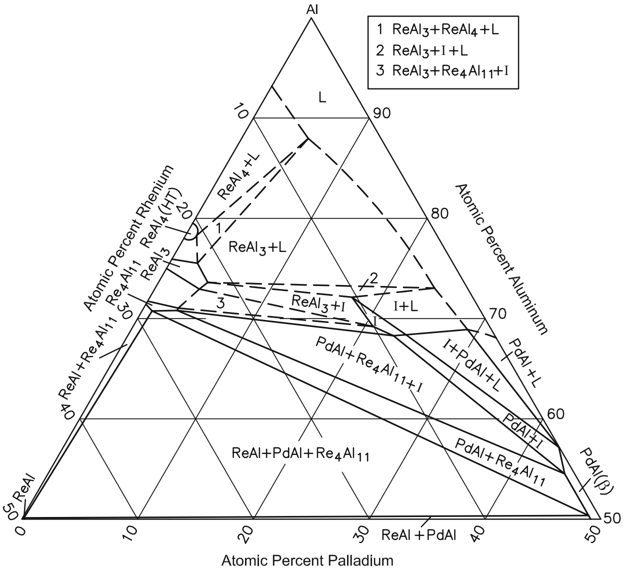

Fig. 2 Al-Pd-Re isothermal section for Al-rich alloys at 1000 °C [2008Bal]

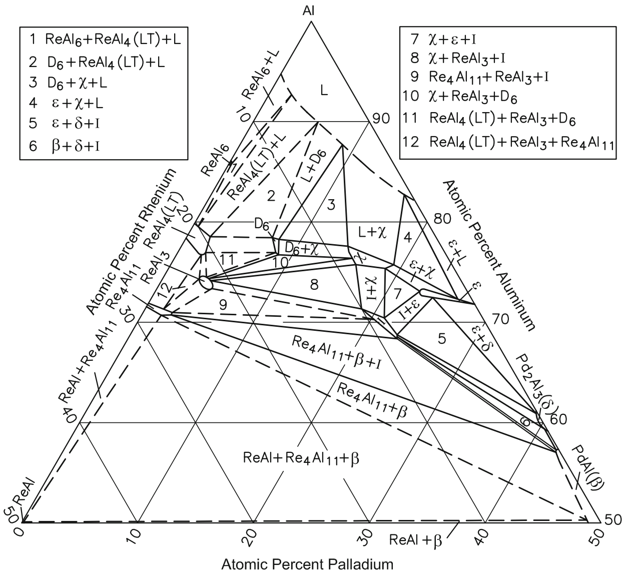

Fig. 3 Al-Pd-Re isothermal section for Al-rich alloys at 790 °C [2008Bal]

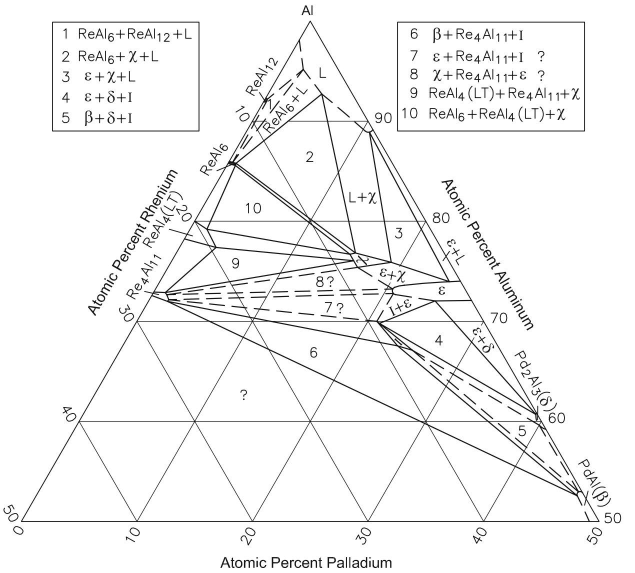

Fig. 4 Al-Pd-Re isothermal section for Al-rich alloys at 700 °C [2008Bal]

scanning and transmission electron microscopy, x-ray powder diffraction, and differential thermal analysis at heating and cooling rates of 5-50 °C per min. The local phase composition was determined by energy dispersive x-ray analysis.

The isothermal sections constructed by [2008Bal] for Al rich alloys at 1100, 1000, 790, and 700 °C are redrawn in Fig. 1 to 4. The isothermal section at 1000 °C was reviewed earlier by [2008Rag]. At 1100 °C (Fig. 1), no ternary phase exists. Along the Al-Re side, $ReAl_4$ (HT), $ReAl_3$, Re_4Al_{11}, and ReAl are present and dissolve up to 2.0, 4.3, 3.0, and ~0 at.% Pd, respectively. On the Al-Pd side, the Al-rich liquid extends to more than 30 at.% Pd. It forms tie-lines with PdAl (β), $ReAl_4$ (HT), $ReAl_3$, and Re_4Al_{11}. The isothermal section at 1000 °C, reviewed in [2008Rag] and reproduced in Fig. 2, shows the icosahedral phase I with a significant homogeneity region. At 790 °C (Fig. 3), the decagonal phase D_6 is present around the composition ~ $Al_{78}Pd_8Re_{14}$. Also, the ternary phase χ is present in the composition range from about $Al_{77.6}Pd_{14.4}Re_{8.0}$ to $Al_{75.6}Pd_{19.5}Re_{4.9}$ [2008Bal]. The ε phase dissolves 4.4 at.% Re. Re_3Al_{11} dissolves up to 2.2 at.% Pd. The binary phase $ReAl_3$, which decomposes at 946 °C [2008Bal], is present at 790 °C in the ternary region due to stabilization by Pd. At 700 °C (Fig. 4), the decagonal D_6 phase is not stable. The ε phase dissolves up to 6 at.% Re. The triangulations marked 7 and 8 in Fig. 4 are tentative.

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