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Al-B-Ti (Aluminum-Boron-Titanium)

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The addition of very small amounts of Ti (~0.005 wt.%) and B (~0.001 wt.%) to liquid Al has a remarkable grain-refining effect. The previous work on this ternary system by [1972Max, 1985Abd1, 1985Abd2, 1989Hay] (compiled in [1995Vil]) pertain to the liquid-solid equilibria near the Al-corner and an isothermal section at 650 °C. Recent work confirms that the diborides AlB_2 and TiB_2 do not form a continuous solid solution.

Binary Systems

The Al-B phase diagram [1994Dus] contains two established compounds AlB_2 and AlB_{12}. The high-temperature modification of AlB_{12} and the high-temperature phase AlB_{10} shown in the Al-B diagram of [Massalski2] are now accepted to be impurity-stabilized phases. AlB_2 forms through a peritectic reaction between AlB_{12} and liquid at 1030 °C [1994Dus] (980 °C in [Massalski2]). An updated Al-Ti phase diagram is given separately in this issue. The Ti-B phase diagram [Massalski2] has three intermediate phases: TiB (FeB-type orthorhombic), Ti_3B_4 (Ta_3B_4-type orthorhombic), and TiB_2 (AlB_2-type hexagonal). TiB_2 is a very stable compound with a congruent melting temperature of 3225 °C.

Liquid-Solid Equilibria in Al-Rich Alloys

The liquid/(liquid + TiB_2) phase boundary near the Al corner was determined by [1972Max] at 100 °C intervals, which shows a steep increase in temperature along the Al-TiB_2 join. The liquidus lines corresponding to univariant equilibria and the invariant points could not be determined, as they are too close to the binary sides.

The number and sequence of the invariant reactions in the system depend on the number and nature of the solid phases participating in the liquid-solid equilibria. The key question has been whether AlB_2 and TiB_2 form a continuous solid solution. Their identical crystal structures and very similar lattice parameters appear to favor a continuous solid solution [1989Hay], but the electronic factor appears to oppose this [1998Zup1]. After 1000 h of holding at 800 °C, [1998Zup1] found that two borides (Al-rich and Ti-rich, respectively) are present and that their compositions are close to those of pure AlB_2 and TiB_2. [2001Fje] reported similar results.

Accepting the position found by the majority of researchers that the two borides do not show significant solubility in each other, a schematic liquidus surface, depicting the univariant and invariant reactions near the Al corner, is shown in Fig. 1. The liquidus lines lie very close to the Al corner. Figure 1 also depicts the reaction sequence for Al-rich alloys. The indicated U-type transition reactions are based on the results of [1998Zup2, 2001Fje].

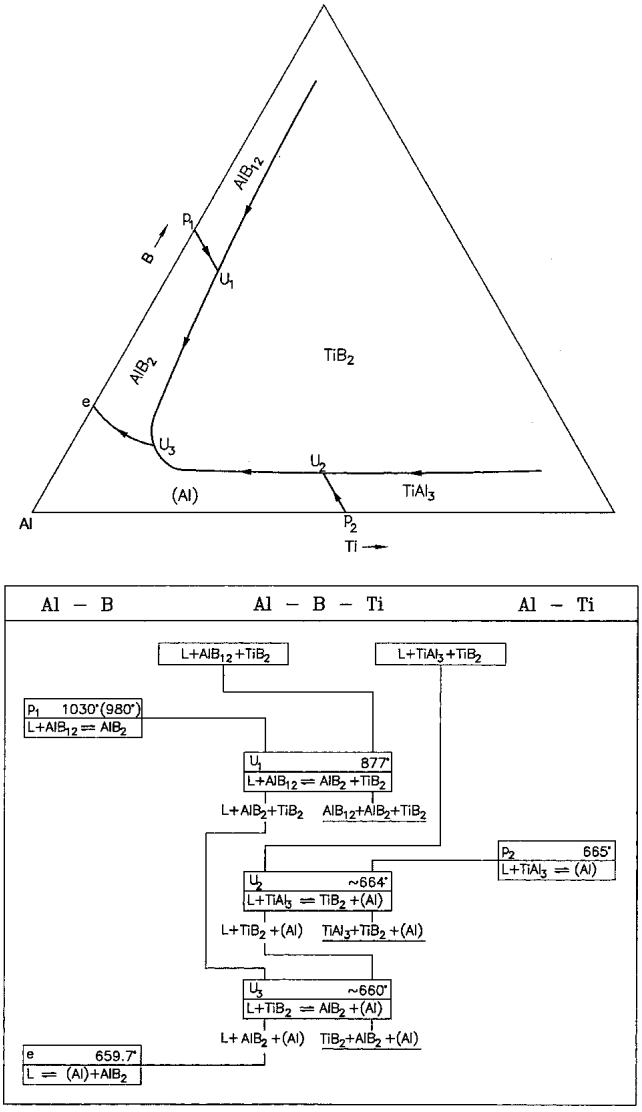

Fig. 1 Al-B-Ti schematic liquidus projection and reaction sequence for Al-rich alloys

Four isothermal sections close to the Al corner were computed by [2001Fje] at 1000, 900, 800, and 700 °C. If the temperature of the peritectic reaction in the Al-B system (p_1 in Fig. 1) is at 1030 °C [1994Dus], a tie-triangle of (L + AlB_2 + AlB_{12}) should be present in the isothermal sections at 1000 and 900 °C, but they are not seen in the computed sections of [2001Fje]. If the peritectic temperature is 980 °C as given in [Massalski2], this tie-triangle should be present in the section at 900 °C. The computed isothermal sections of [2001Fje] at 1000 and 800 °C are redrawn tentatively in Fig. 2 to illustrate the change in the phase distribution

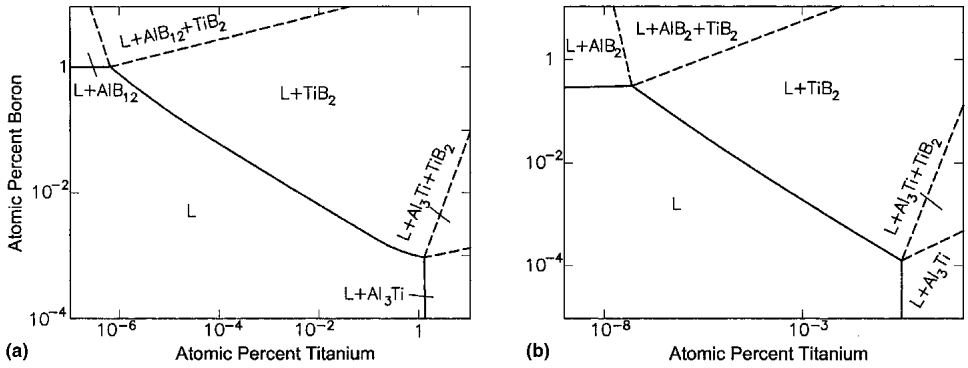

Fig. 2 Al-B-Ti computed isothermal sections at **(a)** 1000 °C and **(b)** 800 °C [2001Fje]

that occurs at the temperature of the transition reaction U_2 (877 °C).

[1997Li] and [1999Li] studied the effect of small additions of B on the location of the $\alpha Ti/(\alpha Ti + \gamma)$, $\alpha_2/(\alpha_2 + \gamma)$, $(\alpha Ti + \gamma)/\gamma$ and $(\alpha_2 + \gamma)/\gamma$ phase boundaries of the Al-Ti binary system. The addition of 0.1 at.% B shifts these boundaries by about 0.5 at.% to the Al -rich side.

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