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

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During the course of their investigation of the role of B and Ti on the grain refinement mechanism in Al-rich Al-Si alloys, [2005Gro] made a thermodynamic assessment of this quaternary system. They presented three computed vertical sections keeping B at a constant 0.1 mass% and Ti at 0.1, 0.218, and 0.3 mass%, respectively.

Binary and Ternary Subsystems

[2005Gro] gave the references of recent assessments of the binary subsystems accepted by them. The binary thermodynamic data were checked for consistency with the more recent experimental results. For the B-Si and B-Ti systems, the interaction parameters were listed from the unpublished reference sources used by them.

The Al-Si-Ti system was recently reviewed by [2005Rag1]. [2005Gro] carried out a new assessment of this system. Two ternary phases $Ti_7Al_5Si_{14}$ (denoted τ_1) and $Ti_3Al_2Si_5$ (denoted τ_2) were accepted and modeled as stoichiometric compounds. The Si-solubility in $TiAl_3$ was taken into account. The description of the other Al-Ti and Si-Ti phases was the same as in the accepted binary assessments, neglecting the third component solubility. The Al-B-Ti system was reviewed by [2005Rag2], who concluded that the diborides AlB_2 and TiB_2 do not have any significant mutual solid solubility. [2005Gro] took the same stand and modeled the diborides as two separate phases without any solubility. Since no ternary phases or ternary solubilities exist in this system, the phase equilibria can be calculated from the binary data sets. The Al-B-Si ternary system is reviewed in this issue. The boride in equilibrium with the Al-Si melt is AlB_{12} (with dissolved Si) and not SiB_6. However, [2005Gro] modeled $Al_3B_{48}Si$ as a stoichiometric compound, instead of a solid solution based AlB_{12}. No data are available for the B-Si-Ti ternary system. Here, the ternary extrapolation of the binary data was done by [2005Gro].

Quaternary Phase Equilibria

With the above binary and ternary descriptions, the quaternary phase equilibria were calculated, without introducing any additional interaction parameters. [2005Gro] presented three vertical sections at 0.1B-0.1Ti, 0.1B-0.218Ti, and 0.1B-0.3Ti (mass%), respectively. These sections are shown Fig. 1-3. The stoichiometric ratio for TiB_2 is 0.1B:0.218Ti (in mass%). For all B:Ti ratios, TiB_2 is the primary phase of crystallization, due to its much larger thermodynamic stability as compared to AlB_2. TiB_2 is thus a potential nucleating agent to promote grain refinement.

In Fig. 2, a very narrow four-phase field of L + (Si) + TiB_2 + AlB_2 is indicated just above the five-phase invariant horizontal line. The quaternary eutectic reaction seen in Fig. 1 and 2 is L ↔ (Al) + (Si) + TiB_2 + AlB_2. The quaternary eutectic temperature is at 576.9 °C (only 0.1°C lower than the binary Al-Si eutectic temperature). This rules out the lowering of the eutectic temperature as a mechanism of grain

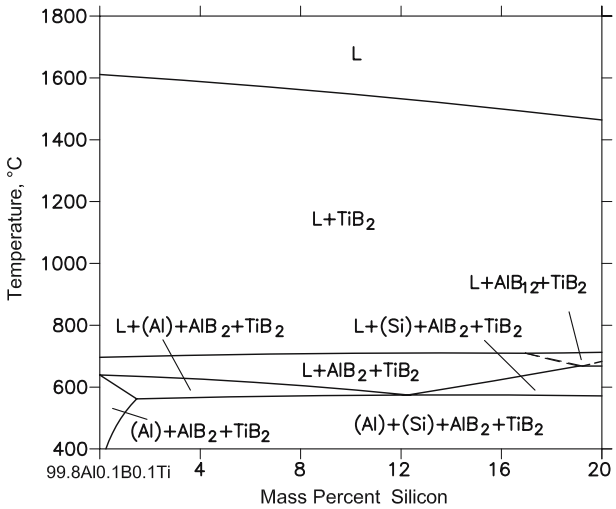

Fig. 1 Al-B-Si-Ti computed vertical section at 0.1B-0.1Ti (mass%) [2005Gro]

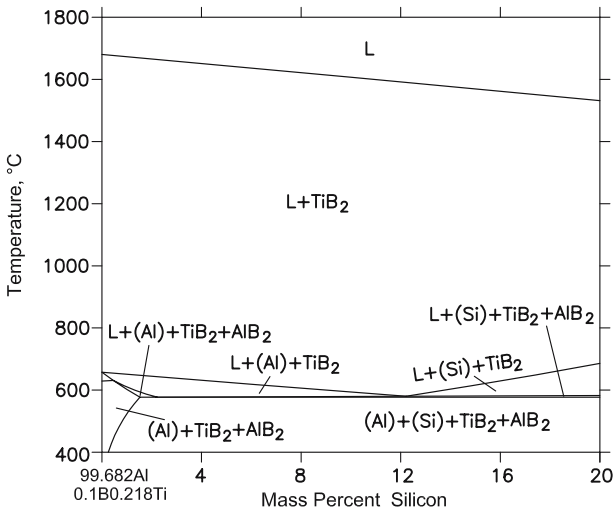

Fig. 2 Al-B-Si-Ti computed vertical section at 0.1B-0.218Ti (mass%) [2005Gro]

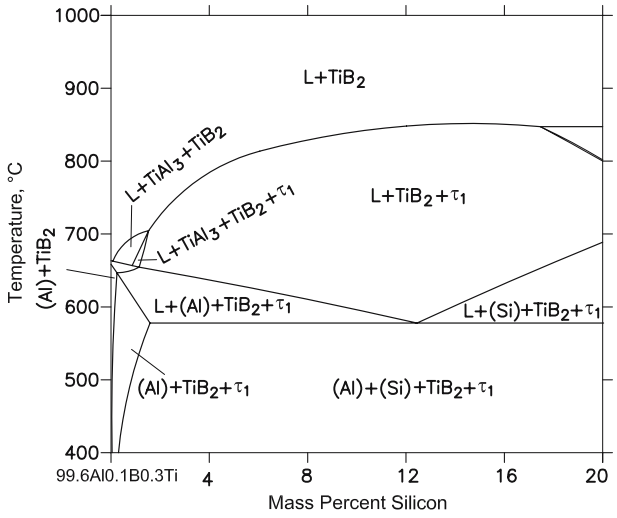

Fig. 3 Al-B-Si-Ti computed vertical section at 0.1B-0.3Ti (mass%) [2005Gro]

refinement. The computed eutectic liquid composition is 12.5 mass% Si, 0.01 mass% B, and 2.9×10^{-11} mass% Ti. In Fig. 3, with Ti in excess of the stoichiometric ratio for TiB_2, the formation of AlB_2 is ruled out. Instead, excess Ti forms the ternary compound $Ti_7Al_5Si_{14}(\tau_1)$. The quaternary eutectic reaction here is $L \leftrightarrow (Al) + (Si) + TiB_2 + \tau_1$. It apparently occurs at a temperature very close to that of the quaternary eutectic reaction in Fig. 1 and 2.

References

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