

## The Al-Si Phase Diagram

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Binary phase diagrams “map out” the relationship between composition and phase occurrence as a function of temperature under equilibrium conditions that involve very slow heating and cooling rates. While metals production involves faster heating and cooling rates, non-equilibrium conditions, the phase diagram remains the starting point for our understanding of alloy systems as it teaches us about melting and solidification temperatures, the solidification sequence, equilibrium phases that can form, solubility limits for alloy or impurity additions and dissolution temperatures for second phases.

The Al-Si phase diagram, a diagram of considerable commercial significance, is the starting point for developing more complex alloys and for understanding their behavior. Si is a common impurity in aluminum alloys, but it is also a deliberate alloying addition in both cast and wrought Al alloys. Cast Al alloys can contain Si in amounts from about 5 to 22 weight percent. At this level, Si improves the fluidity and castability of aluminum. The 3xx.x and the 4xx.x cast alloys (US designations of the Aluminum Association) are very popular commercially. Hypereutectic (alloys with greater than 12.6% Si, the eutectic composition) contain primary Si particles that provide improved wear resistance. Near-eutectic Al-Si alloys are popular casting alloys and can be cast using a variety of techniques: sand casting, die casting and permanent mold casting are most common.

The binary Al-Si phase diagram was first studied by Fraenkel of Germany in 1908. It is a relatively simple binary diagram where there is very little solubility at room temperature for Si in Al and for Al in Si. Thus, the terminal solid solutions are nearly pure Al and Si under equilibrium conditions. The currently accepted diagram, Figure 1, is based on the study by Murray and McAlister [1] in 1984. The melting points of Al and Si are, respectively, 660.45 and 1414 °C, while the eutectic reaction occurs at 12.6 wt. % Si and  $577 \pm 1$  °C. The maximum solubility of Si in Al occurs at the eutectic temperature and is 1.65 wt. %. At least up to the late 1950's, the eutectic was believed to be at 11.6 wt. % Si. Modification of the eutectic by very small Na additions has been known since the 1920s. Modifiers like Na shift the eutectic to higher silicon contents, around 14 wt. %, preventing precipitation of hypereutectic Si while refining the structure of the eutectic. This increases both strength and ductility substantially.

The talk will present the microstructure of Al-Si alloys up to 50% Si, as well as illustrate the effect of various minor additions that modify the eutectic. Examples of the microstructure of some of these alloys are given in Figures 1 to 6.

### Reference

[1] J.L. Murray and A.J. McAlister, **Bull. Alloy Phase Diagrams**, Vol. 5, No. 1, Feb. 1984.

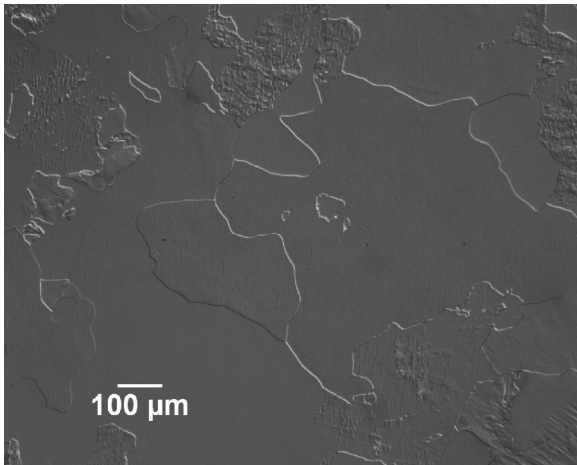


Fig.1 99.999% pure Al, Keller's etch, DIC.

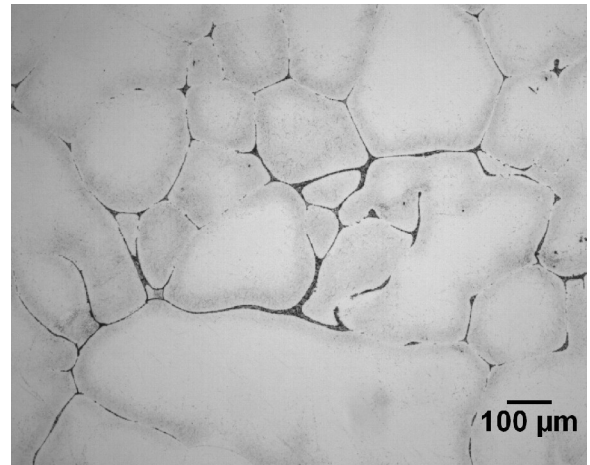


Fig. 2 Al - 1% Si - 0.45% Mg, SBlue etch.

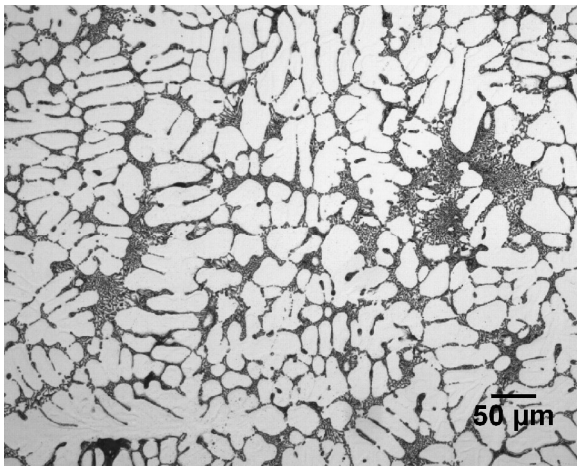


Fig. 3 Al - 7.12% Si, SBlue etch.

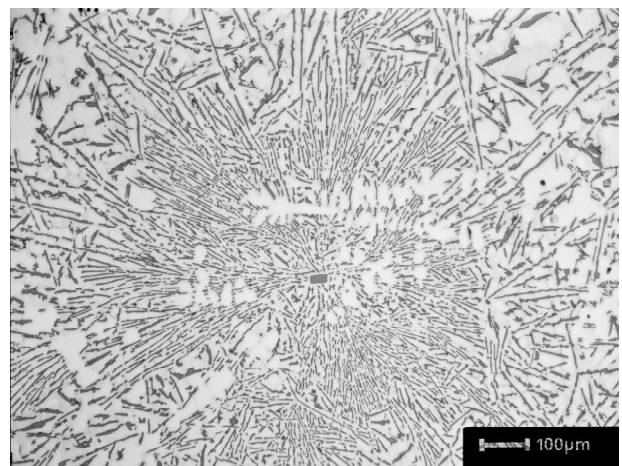


Fig. 4. Al - 12 % Si, SBlue etch.

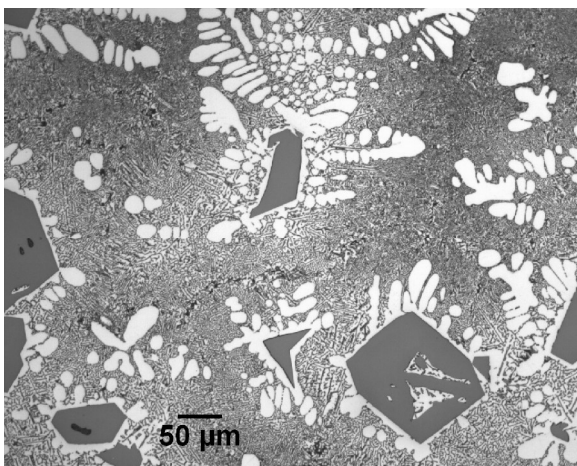


Fig. 5. Al - 19.85% Si, SBlue etch.

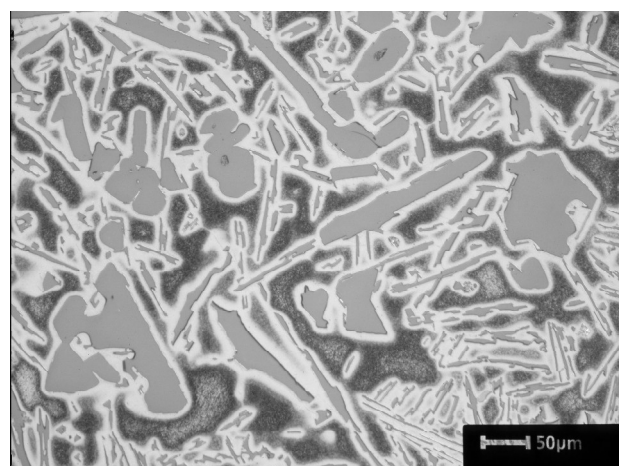


Fig. 6. Al - 25% Si - 1.4% Fe, Weck's reagent.