The Growth and Morphological Stability of a Precipitate in a Multi-component Alloy

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On the work on the interface morphology by Mullins and Sekerka, important advances have been made in many extensions to various situations of the interfacial evolution and morphological stability of precipitates or particles. In recent years, the growth kinetics of precipitates or particles in the multi-component alloys have been investigated for the optimization of solute compositions in terms of microstructural properties in experimental and industrial applications. However, these works, based on a time power law assumption in the initial growth condition, attempt to exactly solve the unsteady diffusion equations in order to overcome Mullins and Sekerka's simplifying assumption of steady Laplacian equations. Although the exact time-dependent solutions to unsteady diffusion equations are solved in the confluent hypergeometric function, the growth velocity of the precipitate or particle becomes physically meaningless initially infinite. As a result, the morphological stability criteria of the precipitate or particle may seriously deviate from that in the pure melt made by Mullins and Sekerka. Actually, Mullins and Sekerka's stability criterion of the precipitate or particle in the pure melt is an idealized approximation of the stability criterion in dilute multi-component alloys and the later is a consistent modification of the former without too large deviation. Through a rigorous magnitude analysis to steady and unsteady growth regions of the precipitate in the multi-component alloy, we clarify the contributions of unsteady diffusion equations in different sub-regions for the dynamics model of the precipitate. By using the asymptotic method, we find the uniformly valid asymptotic solution in the entire region for the dynamics model. With the analytical solution we show the growth velocity, interfacial evolution, absolute and relative stability criteria of the precipitate in the multi-component alloy. The critical stability radii for the absolute and relative stability criteria of the precipitate in the multi-component alloy are determined. The morphological stability of the precipitate may be controlled by adjusting the solute compositions in the multi-component alloy melt.