On fibrous growth during the discontinuous precipitation: A phase-field study

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Taking place at grain boundaries, discontinuous precipitation is a solid-state phase transformation in which a supersaturated α_0 matrix decomposes into a solute-rich β-precipitate and a depleted α-phase. The decomposition is systematically accompanied by a grain boundary migration, which is required for the growth of the two product phases. As a result, the rate-controlling step for the reaction is essentially grain boundary diffusion [1]. Discontinuous precipitation results in morphologies that are typically lamellar. However, fibrous and globular structures are also observed, for example in the Cu-Co alloy [2].

We have previously developed a phase-field model for discontinuous precipitation, and many two-dimensional (2D) simulations have been carried out to survey some fundamental features/aspects of discontinuous precipitation, such as the role of the ratio of volume to interface diffusivities [3]. In particular, it has been observed that volume diffusion contribution, gave rise to a growth kinetics of β-precipitates analogous to a growing needle crystal in a channel.

In the present contribution, three-dimensional (3D) phase-field simulations have been performed to investigate the morphological stability of lamellar precipitates during discontinuous precipitation. The effect of a numerically induced noise on the stability of the β-precipitates is investigated, in the presence of volume diffusion. The numerical noise has resulted in a symmetry breaking, which leads to a transition to fibrous growth for a sample thickness above a critical value. Due to the high supersaturations necessary to obtain tractable simulation times in our phase-field model, α-lamellae instead of β ones have been observed to form the minor phase. Consequently, the lamellar to fibrous transition has yield α-fibers rather than β ones.

The observed behavior is analogous in many points to the one of eutectic solidification fronts, where a transition from lamellae to fibers also takes place if the volume fraction and/or the system size are varied. In addition, further increase of the sample thickness has resulted in the formation of a second fiber of the depleted phase; which suggests that our system's response to numerical perturbation, presents a certain periodicity along the z-axis. As a result, the growth of β-fibers arranged according to a hexagonal lattice has been surveyed. It turns out that the viability of β-fibers requires cutting volume diffusion to prevent their interaction.

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