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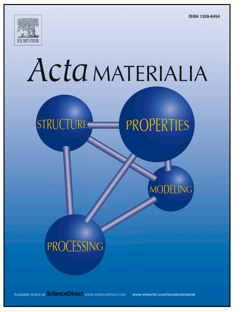

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Thermal-field effects on interface dynamics and microstructure selection during alloy directional solidification

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Abstract

We carry out three-dimensional phase-field simulations to model unique experimental observations of cellular and dendritic solidification structures formed under diffusive growth conditions in the DSI (Directional Solidification Insert) of the DECLIC (DEvice for the study of Critical LIquids and Crystallization) aboard the International Space Station. We had previously shown experimentally that complex thermal conditions affect the stationary position of the solid-liquid interface, as well as its dynamics of relaxation towards this stationary position over a finite time after the onset of sample pulling. Here, we discuss the effects of thermal diffusion within the adiabatic zone of the directional solidification setup and of latent heat release at the solid-liquid interface by means of quantitative phase-field simulations. Simulations and experiments characterize the entire evolution of the primary spacing of cellular/dendritic array structures from the onset of morphological instability to the establishment of the final steady-state spacing, including the transient coarsening regime associated with a sharp increase of spacing. Accounting for these thermal effects leads to a major improvement in the agreement between simulations and microgravity measurements for both the time of occurrence of morphological instability after the start of the experiment and the subsequent spacing evolution, which are not accurately predicted using the standard frozen temperature approximation.

Keywords: Directional solidification, Phase field, Microstructure formation, Alloys

1. Introduction

Columnar microstructures form when a liquid material solidifies under a temperature gradient. Resulting spacings between primary or secondary branches in these microstructures affect their mechanical proper-

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