# Microscale Phase-Field Study of Crystal Growth and Particle Dynamics in Directionally Solidified Colloidal Suspensions

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Solidification of colloidal suspensions during ice-templating (freeze-casting) generates porous and frequently anisotropic microstructures, as the advancing ice front rejects suspended particles and drives their accumulation ahead of the interface [1, 2]. This study focuses on a microscale description of this phenomenon, emphasizing the evolution of crystal growth and the dynamics of colloidal particles under directional solidification. The methodology relies on phase-field simulations conducted within representative volume elements using the PRISMS-PF framework.

The model enables detailed tracking of the morphology and kinetics of the solid–liquid interface, together with particle redistribution, segregation, and local packing in the region ahead of the growing crystals. Special attention is given to the influence of thermal conditions specifically the local cooling rate and temperature gradient on interface stability, crystal spacing, and the emergence of particle-enriched zones. The formulation is designed to capture key mechanisms identified in recent freeze-casting research, including particle-front interactions and growth-front instabilities that drive hierarchical pattern formation [2].

Overall, the proposed microscale model provides a mechanistic basis for understanding how local solidification conditions govern crystal growth and colloidal particle behavior, and it establishes a foundation for future quantitative analyses of microstructure development in freeze-cast materials.

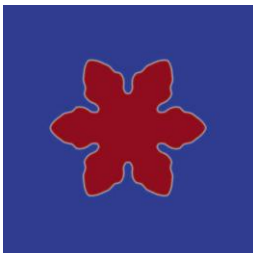

Figure 1. Example of anisotropic ice dendrite growth.

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