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A Fully Implicit Approach to Phase Field Modeling of Dendritic Solidification

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We develop and characterize a fully-coupled, fully-implicit approach to phase field modeling of dendritic solidification. Predictive simulation of dendrite growth in pure metals and alloys remains a significant challenge in the field of materials science, as micro-structure formation during the solidification of a material plays an important role in the properties of the solid material. Our approach consists of a finite element spatial discretization of the fully-coupled nonlinear system, which is treated implicitly in time with a preconditioned Jacobian-free Newton-Krylov (JFNK) method. The key to efficient implementation of JFNK is effective preconditioning. As the dominant cost of JFNK is the linear solver, effective preconditioning reduces the number of linear solver iterations per Newton iteration. We discuss a preconditioning strategy based on algebraic multigrid and block factorization that allows an efficient, implicit time integration. We provide numerical examples and compare our method to explicit methods to evaluate efficiency, accuracy and algorithmic scalability.