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Nanosecond freezing of gallium under extreme effective cooling rates. Part 2: Theory and Simulations[1] JONATHAN BELOF, PHILIP MYINT, Lawrence Livermore National Laboratory, JUSTIN BROWN, BRIAN STOLTZFUS, Sandia National Laboratories — Experiments recently performed using the pulsed-power machine Thor, shocklessly compressing thin liquid gallium (Ga) samples at a range of loading rates (10^6 – 10^7 sec^{-1}) and peak pressures (20 – 45 GPa), demonstrate freezing at very high driving force with nanosecond solidification kinetics, as presented in the previous accompanying talk. Building on a previously developed model for the compression-induced solidification of water to the high-pressure ice VII phase, a transient nucleation and growth theory for the time-dependent phase transition from the liquid to the body-centered tetragonal structure of Ga has been developed and applied toward the analysis of the Ga ramp compression data. Having coupled the solidification kinetics model to the hydrodynamic field equations, numerical simulations reveal an intimate relationship between ramp compression loading rate, wave propagation distance and the observed timescale for solidification kinetics. Simulations of multiple Ga ramp experiments demonstrate nearly quantitative agreement with a single physics-based model, with the high level of accuracy attributed to the explicit inclusion of the liquid-solid interfacial thermodynamics in the kinetics model.

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