GRAVITATIONAL COLLAPSE OF COLLOIDAL GELS

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We investigate the phenomenon of gravitational collapse in colloidal gels via dynamic simulation in moderately concentrated gels formed via arrested phase separation. In such gels, rupture and re-formation of bonds of strength O(kT) permit ongoing structural rearrangements that lead to temporal evolution—aging—of structure and rheology [1]. The reversible nature of the bonds permits a transition from solid-like to liquid-like behavior under external forcing, and back to solid-like behavior when forcing is removed. But such gels have also been reported to undergo sudden and catastrophic collapse of the entire structural network, eliminating any intended functionality of the network scaffold. Although the phenomenon is well studied in the experimental literature, the microscopic mechanisms underlying the collapse remain murky [2-18]. Here we conduct large-scale dynamic simulation to model structural and rheological evolution of a gel subjected to gravitational stress. The model comprises 750,000 Brownian particles interacting via a hard-core repulsion and short-range attractive interactions that lead to formation of a gel, periodically replicated to an infinite system [1]. A body force is applied to the gel, and particle positions, velocities, and pressure are measured throughout simulation, as well as the bulk strain of the gel. Three temporal regimes emerge: slow, pre-collapse evolution; collapse and rapid sedimentation; and long-time compaction producing, to our knowledge, the first large-scale dynamic simulation of gravitational gel collapse. We connect the temporal regimes to distinct phases of structural and rheological evolution. A range of attraction strengths, and their effect on the critical force that triggers collapse, are studied. We find that the initial deformation is slow and linear, and the transition to and scaling of the fast strain rate depends on the strength of gravitational forcing, as is the transition to and rate of the final sedimentation regime, in excellent agreement with experimentally reported behavior [3,9,14]: The detailed microstructural evolution is reported here, along with the dependence of the delay time and speed with attraction strength and magnitude of the applied stress relative to Brownian forces.

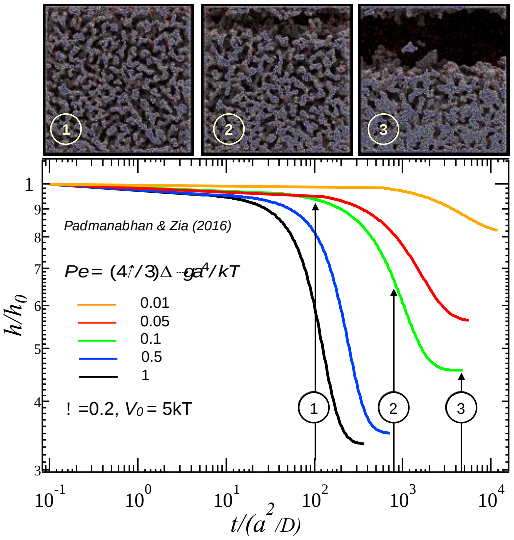

FIGURE 1 – IMAGES: SNAPSHOTS FROM SIMULATION DURING SLOW COMPACTION AND RAPID GEL COLLAPSE. PLOT: EVOLUTION OF BULK HEIGHT

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