Foam coarsening dynamics within non-Newtonian fluids

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Injecting additive-stabilized foam fluids presents a promising approach for geological carbon storage (GCS) in complex reservoir environments. The effectiveness of this technique critically depends on foam stability and flow behavior within a confined space. However, the mechanisms governing the transition from foam coarsening to structural equilibrium, especially in non-Newtonian systems, remain insufficiently understood. This study investigates the gas-diffusion-driven coarsening of quasi-2D foams in non-Newtonian fluids, and the interaction between fluid rheology and gas diffusion in shaping foam morphology. Non-Newtonian precursor fluids were prepared using cellulose nanofibrils (CNF), and their rheological properties were systematically correlated with foam evolution. Fluorescence imaging combined with custom analysis tools enabled quantitative tracking of bubble morphology and dynamics. Results show that increasing CNF concentration leads to a nonlinear enhancement in foam stability, as indicated by extended half-life times. Analysis of bubble size distribution and lamella curvature revealed that higher CNF content suppresses gas diffusion and bubble rearrangement, especially within confined pore spaces. Overall, this work reveals how non-Newtonian rheology modulates foam stability and structur, offering valuable insights into the design of more effective foam-based GCS strategies under challenging reservoir conditions.

Keywords:
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