

Shear Banding in Carbon Nanotube Networks

Erik K. Hobbie, NIST, Gaithersburg, Maryland

A shear-banding instability associated with flow-induced clustering in entangled non-Brownian carbon nanotube suspensions is described. In situ birefringence, dichroism, depolarized light scattering and video microscopy measurements under shear are combined with strain-rate and stress-controlled rheometry to characterize the transient and steady-state non-equilibrium structure of the suspensions as a function of confinement, concentration and shear stress. Based on these measurements, we construct a non-equilibrium phase diagram that maps the evolution from solid-like nanotube networks to flowing nematics under an applied stress. Although the carbon nanotubes are strongly non-Brownian, we find features characteristic of first-order phase transitions, including a discontinuity in the nematic order parameter at the isotropic-(para)nematic phase boundary. Using simple physical arguments, we account for the shape of the coexistence curves, as well as the dependence of the order parameter on concentration and stress. Simple scaling arguments are also used to relate the fractal morphology of the quiescent nanotube network to the measured shear modulus and yield stress. Practical implications of this flow instability for the processing of nanotube suspensions and melt carbon-nanotube polymer composites will be discussed.