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Rheological and Rheo-NMR Studies of Biopolymer and Polymer Solutions and Gels

Rheology is the study of the flow or deformation of matter. Rheology provides information to better understand and predict how materials behave under shear and elongation forces during industrial or biological processes. Rheological testing was performed on polymer and biopolymer solutions to characterize their material properties upon loading of nanoparticles. Polymers and biopolymers are of interest in many industrial and biological settings because of their broad presence and extraordinary range of properties. The addition of nanoparticles to polymer solutions cause striking changes in how these polymers react under deformation, useful for the design of new materials with controlled shear-dependent properties. Suspensions of silicon dioxide nanoparticles, diameter of 10-20 nanometers, were added at concentrations by weight varying from 1-10% to three different semi-dilute polymer solutions: the polysaccharide locust bean gum, the biopolymer xanthan gum, and polyacrylamide. 1% locust bean and 1% xanthan gum solutions showed an increase in viscosity with the addition of nanoparticles, but with similar respective shear-thinning and weak gel behavior. The rheological behavior of 1% polyacrylamide solution, on the other hand, changed from the shear-thinning typical of entangled polymer solutions to an anomalous shear-thickening behavior with the addition of nanoparticles. Rheo-NMR velocity imaging performed using a cone and plate geometry revealed the existence of shear banded flow for 1% polyacrylamide solutions containing 10% silicon dioxide nanoparticles. Shear banding is a hydrodynamic instability where the flow field is inhomogeneous with two macroscopic regions of different shear rates. Shear banding has been observed in high concentration (3%) polyacrylamide solutions. Here, polymer-particle interactions have induced shear banding behavior at a low polymer concentration.