Viscoelastic Structuring of Hybrid Fumed Silica–Cellulose Nanocrystal Suspensions toward Advanced Emulsion Stabilization

Hanie Alizadeh, Rajinder Pal

Department of Chemical Engineering, University of Waterloo, Waterloo, Ontario, Canada, N2L 3G1

halizade@uwaterloo.ca

The rheological behavior of hybrid suspensions composed of fumed silica nanoparticles (T30) and cellulose nanocrystals (CNC) was investigated to understand the combined effects of particle concentration and nanoparticle interactions on steady shear and viscoelastic properties. Steady shear measurements were conducted over a broad range of T30 concentrations, while oscillatory rheology was performed on selected high-silica formulations (7 and 8 wt% T30).
All suspensions exhibited shear-thinning behavior, indicating progressive microstructural breakdown under increasing shear rate. The addition of CNC significantly increased the suspension consistency, suggesting enhanced particle–particle interactions and structural connectivity.
Oscillatory measurements revealed elastic-dominated behavior ($G' > G''$) across the entire investigated frequency range for the selected formulations. The incorporation of CNC led to a substantial increase in both storage and loss moduli, with a more pronounced enhancement in the elastic response. In particular, the storage modulus increased by more than one order of magnitude (from ~200 Pa to ~8000 Pa at 1 rad/s), indicating the formation of a strongly interconnected viscoelastic network.
The enhanced rheological behavior is attributed to synergistic interactions between fumed silica aggregates and rod-like CNC particles, which promote network formation and mechanical reinforcement. Gap-dependent measurements showed negligible variation in the measured moduli, confirming the reliability of the rheological data.
These findings demonstrate that small additions of CNC can transform silica suspensions into strongly interconnected gel-like viscoelastic networks, which can be leveraged to couple bulk rheological structuring with interfacial stabilization mechanisms, providing a pathway toward dual-stabilized emulsion systems.

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Rheology
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