UNIVERSITY of HOUSTON

CULLEN COLLEGE of ENGINEERING

Stretched Polymer Physics, Pinch-off Dynamics and Printability of Polymeric Complex Fluids

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Chemical Engineering Senior Room (S144E)*

*The Senior Room is accessed through an external door on the south side of the building (across from the power plant), on the first floor

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Liquid transfer and drop formation/deposition processes associated with printing, spraying, atomization and coating flows involve complex free-surface flows including the formation of columnar necks that undergo spontaneous capillary-driven instability, thinning and pinchoff. For simple (Newtonian and inelastic) fluids, a complex interplay of capillary, inertial and viscous stresses determines the nonlinear dynamics underlying finite-time singularity as well as self-similar capillary thinning and pinch-off dynamics. In rheologically complex fluids, extra elastic stresses as well as non-Newtonian shear and extensional viscosities dramatically alter the pinch-off dynamics. Stream-wise velocity gradients that arise within the thinning columnar neck create an extensional flow field, and many complex fluids exhibit a much larger resistance to elongational flows than Newtonian fluids with similar shear viscosity. Characterization of the response to both shear and extensional flows that influence dispensing and liquid transfer applications requires bespoke instrumentation not available, or easily replicated, in most laboratories. Here we show that dripping-onto-substrate (DoS) rheometry protocols that involve visualization and analysis of capillary-driven thinning and pinch-off dynamics of a columnar neck formed between a nozzle and a sessile drop can be used for measuring extensional viscosity and relaxation time of polymeric complex fluids. We show that DoS rheometry enables characterization of low viscosity printing inks and polymer solutions that are beyond the measurable range of commercially-available capillary break-up extensional rheometer (CaBER). We find that the extensional relaxation times of semi-dilute, unentangled, uncharged polymers in good solvent exhibit a stronger concentration than observed in shear rheology, or anticipated by blob models developed for relaxation of weakly perturbed chains in a good solvent. We show that the interplay of electrostatic and hydrodynamic stretching leads to unexpected and unexplored concentration-dependent response for polyelectrolyte solutions. Finally we elucidate how polymer composition, flexibility, extensibility (molecular weight), and charge influence hydrodynamics and interactions of strongly stretched chains, and consequently, determine processability and processing timescale for printing, coating, dispensing

Biography:

Dr. Vivek Sharma is an Assistant Professor of Chemical Engineering at the University of Illinois, Chicago. Before joining UIC in November 2012, he worked as a post-doctoral research associate in Mechanical Engineering at Massachusetts Institute of Technology. He received his Ph. D. (Polymers/MSE, 2008) and M. S. (Chemical Engineering, 2006) from Georgia Institute of Technology, an M. S. (Polymer Science, 2003) from the University of Akron, and a bachelor's degree from IIT Delhi. Dr. Sharma's research interests broadly lie in optics, dynamics, elasticity, and self-assembly (ODES) of complex fluids and soft materials. At UIC, Dr. Sharma's Soft Matter ODES-lab combines experiments and theory to pursue the understanding of, and control over, interfacial and nonlinear flows of complex fluids. ODES-lab focuses on the interplay of (a) viscoelasticity and capillarity for printing applications and extensional rheometry, and (b) interfacial thermodynamics and hydrodynamics in fizzics (the science of bubbles, drops, thin films, fibers, jets, sprays, emulsions and foams). Dr. Sharma was selected as the Distinguished Young Rheologist by TA Instruments in 2015, and won the 2017 College of Engineering Teaching Award at UIC.

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