MRS/E-MRS Joint Student Chapter, Hasselt University and IMO-IMOMEC

2019 Materials Science Lecture Series:
ADVANCED MATERIALS

Wednesday, July 3rd, 2019
10:30h
Hasselt University, Building D, Room H1

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

By

Prof. dr. **Vivek Sharma**

Chemical Engineering, University of Illinois at Chicago, IL.

Biography: Prof. 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 Tech., an M.S. (Polymer Science, 2003) from the University of Akron, and a bachelor's degree from IIT Delhi. Prof. 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, focused 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, jets, fibers, emulsions and foams). Prof. Sharma was selected as the Distinguished Young Rheologist by TA Instruments in 2015, won the 2017 College of Engineering Teaching Award at UIC, and was awarded 3M Non-Tenured Faculty Award, 2019.

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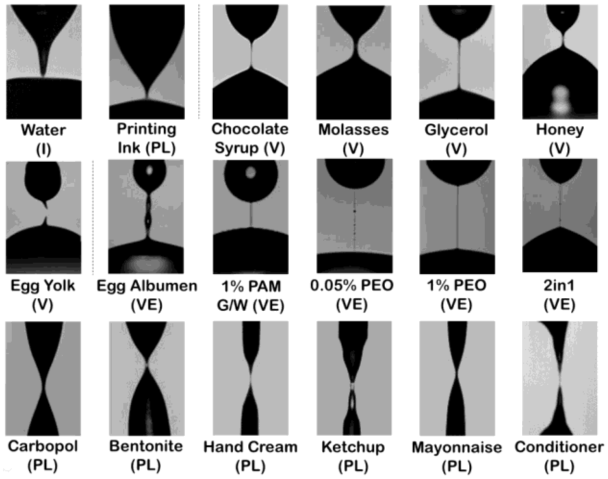
Pinch-off dynamics and Printability of Complex Fluids



Abstract: 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 pinch-off. For simple (Newtonian and inelastic) fluids, a complex interplay of capillary, inertial and viscous stresses determines the neck thinning dynamics. In rheologically complex fluids, extra elastic stresses as well as non-Newtonian shear and extensional viscosities dramatically alter the pinchoff 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. Here we show that dripping-onto-substrate (DoS) rheometry protocols we developed recently 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 extensional relaxation time of polymeric complex fluids. We show that the DoS rheometry protocols enable the 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 dilute and semi-dilute, unentangled polymers in good solvent exhibit much stronger concentration dependence than observed in shear rheology response or anticipated by blob models developed for relaxation of weakly perturbed chains in a good solvent. In this contribution, we contrast the pinch-off dynamics and extensional rheology response of aqueous solutions of 2-hydroxyethyl cellulose (HEC) and polyethylene oxide (PEO) characterized using dripping-onto-substrate (DoS) rheometry to elucidate how change in chemical structure (or polymer choice) influences rheological and processing behavior. We discover that our pursuit involves myriad, intertwined quests and insights into conformation-dependent hydrodynamic and excluded volume interactions, Pincus' tension blobs, finite extensibility effects, as well as coil-stretch transition and hysteresis. We show that the influence of chemistry can be evaluated a priori, using three macromolecular parameters: flexibility, extensibility and segmental dissymmetry.

Selected Publications

1). J. Dinic and V. Sharma, "Macromolecular relaxation, strain and finite extensibility determine visco-elastocapillary thinning and extensional viscosity of polymer solutions", Proceedings of National Academy of Sciences (2019)
2). Y. Zhang, S. Yilixiati, C. Pearsall and V. Sharma, "Nanoscopic terraces, mesas and ridges in stratifying foam films sculpted by supramolecular oscillatory surface forces", ACS Nano, 10(4), 4678-4683 (2016).
3). V. Sharma, M. Crne, J. O. Park and M. Srinivasarao, "Structural origin of circularly polarized iridescence in Jeweled Beetles," Science, 325, 449-452 (2009).
4). V. Sharma, K. Park and M. Srinivasarao, "Shape separation of gold nanorods using centrifugation," Proceedings of National Academy of Sciences, 106(13), 4981-4985 (2009).

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