From shear to extensional instabilities: The essence of nonlinear melt rheology

Shi-Qing Wang, Mesfin Tsige, Y.X. Zheng, R.C. Yuan and X.Y. Zhao
University of Akron, US 44325

Since the essence of nonlinear melt rheology is about figuring out why chain deformation occurs, when it ceases to grow and how it diminishes upon termination of external straining, we see the subject as comprised of three parts associated with three core, previously unexplored, concepts: (a) finite cohesion of the network, (b) molecular force imbalance, and (c) entanglement lock-up. This talk describes them using concrete examples. The force imbalance produces non Rouse-chain-retraction, manifesting various forms of instabilities including shear banding and filament failure during respective startup shear and extension and non-quiescent stress relaxation (elastic yielding) from step (both shear and extension) strain. In contrast, below a threshold strain, no chain retraction of any form occurs, as confirmed by SANS measurements (Wang et al., Physical Review X 7, 031003) and MD simulations (Xu et al., ACS Macro Letters 7, 190; Hsu and Kremer, Phys. Rev. Lett. 121, 167801). This reveals an entropic barrier to ensure finite cohesion of the entanglement network. Finally, interchain uncrossability can produce "infinitely" strong pulling force in melt extension to lock up entanglement so that only chain scission can permit a cascade of disentanglement events leading to melt rupture.