Spatially Resolved Quantitative Rheo-optics of Complex Fluids in a Microfluidic Device

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In this study, we use micro-particle image velocimetry (μ-PIV) and adapt a commercial birefringence microscopy system for making full-field, quantitative measurements of flow-induced birefringence (FIB) for the purpose of microfluidic, optical-rheometry of two worm-like micellar solutions. In combination with conventional rheometric techniques, we use our microfluidic rheometer to study the properties of a shear-banding solution of cetylpyridinium chloride (CPyCl) with sodium salicylate (NaSal) and a nominally shear thinning system of cetyltrimethylammonium bromide (CTAB) with NaSal across many orders of magnitude of deformation rates ($10^{-2} \leq \dot{\gamma} \leq 10^{4}$ s^{-1}). We use μ-PIV to quantify the local kinematics and use the birefringence microscopy system in order to obtain high-resolution measurements of the changes in molecular conformation in the worm-like fluids under strong deformations in a microchannel. The FIB measurements reveal that the CPyCl system exhibits regions of localized, high optical anisotropy indicative of shear bands near the channel walls, whereas the birefringence in the shear-thinning CTAB system varies more smoothly across the width of the channel as the volumetric flow rate is increased. We compare the experimental results to the predictions of a simple constitutive model, and we document the break-down in the stress optical rule as the characteristic rate of deformation is increased.

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