MEMs Parallel Plate Rheometer for Oscillatory Shear Micro Rheology Measurements

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Motivation

• Novel viscoelastic materials
• Micro scale structure
• Confinement deforms structure
• Alters rheology
• Characterization difficult
• Small sample volumes
• Particle micro rheology does not probe entire micro structure
• Thin film measurements only elastic modulus

MEMs Parallel Plate Rheometer

• 1 mm² nano-positioner applies sinusoidal strain
  • Thermal Actuator
  • 0.1% < γ < 25%
• O(1) um gap set with thin film
• Strain applied to the entire fluid body
• Optical observation
• Storage and loss moduli at 0.5 Hz < f < 500 Hz
• Uses less than 10 nL of fluid

Mechanical Modeling

• Fluid modeled as Voigt Element
• X_s nano-positioner motion
• X_a actuator motion

\[ m_s \ddot{x}_s + \eta \dot{x}_s + \left( 2 + \frac{G}{k_s} \right) x_s = x_a \]

\[ x_{s,\text{loaded}} = |x| \sin(\omega t + \phi) \]

Viscous Fluid Calibration

• Surface tension affects amplitude
• Model predicts general behavior
• ±25% device error on viscosity above 1 Hz
• ±150 Pa error on elastic modulus above 1 Hz

PDMS Thin Films

• Moduli grow with increasing wt.%
• 3 wt.% G’ consistent with DMA
• G’ larger for thinner film
• Trends consistent with observed behavior

Conclusions

• MEMs Rheometer with optical analysis can extract rheology
• Model matches observed phenomenon
• Consistent results for viscous fluids and viscoelastic thin films
• Large frequency domain, \( \sim 3 \) decades, with O(1) um gap sizes
• Redesign of device should improve accuracy and sensitivity