

Micromechanical characterization of complex interfaces

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ABSTRACT

Microrheology offers distinct advantages for measuring the micromechanical properties of interfaces. The length scale introduced by a colloidal probe ensures high sensitivity in probing interfacial rheological behaviour. Additionally, its ability to capture heterogeneities, velocity correlations, and rapid transient dynamics makes interfacial microrheology particularly valuable for studying structured interfaces, biological films, and 2D phase transitions. However, our theoretical understanding remains fragmented, lacking a unified framework and largely confined to specific cases. Moreover, the applicability of the Generalized Stokes-Einstein-Sutherland Relationship at fluid-fluid interfaces remains an open question.

In this talk, we first discuss our recent progress in using interfacial (passive) microrheology to map micromechanical heterogeneities of complex interfaces. We show that heterogeneous interfaces are found in various type of interfaces such as asphaltene-laden interfaces, 2D colloidal crystals and biofilms.

Motivated by these findings, we then propose a theoretical framework for two-point interfacial microrheology. Specifically, we study the case of a Newtonian flat interface modelled by a Boussinesq-Scriven constitutive equation. Extending the work of Levine and MacKintosh (PRE, 2002), we consider the general case of an isothermal asymmetric system where the surface tension changes linearly with the surface-active molecule concentration. An unsteady convection-diffusion equation governs the concentration of active molecules. To model two-point microrheology, we consider one bead driven on a flat fluid-fluid interface by a periodic external force and we study the dynamics of a second bead at a given distance. The driven bead is modelled as an oscillatory point force, which lies in the plane of the interface. We obtain analytical solutions for the deformation field, the single particle power spectrum as well as the longitudinal and transversal pair correlation functions. These quantities are directly extracted by two-point-microrheology data in experiments.

Our theoretical framework facilitates the transient analysis of interfaces containing surface-active molecules. Furthermore, the proposed framework can be extended to incorporate more complex constitutive equations or transport dynamics, further enhancing interfacial microrheology as a powerful characterization technique.