Decoupling shear and dilatational viscoelastic behaviors for complex fluid interfaces

Summer Tein1, Chuck Majkrzak2, Brian Maranville3, Jan Vermant2, Norman J. Wagner1

1Department of Chemical and Biomolecular Engineering, University of Delaware, Newark, DE 19716
2National Institute of Standards and Technology, Gaithersburg, Maryland, USA, 20899
3Department of Materials, ETH Zurich

1. Importance of Interfaces

- Lung surfactants (LS) lower pulmonary compliance to ease the work of breathing.
- ARDS and NRDS (Acute Respiratory Distress Syndrome) are diseases caused by lack of LS thin film stability.
- Emulsion stability can be enhanced by addition of particles/surfactants, which resist shrinkage and growth of the bubbles.

2. Lung Surfactants: Case Study of Interfacial Complexity

Lung surfactants and their mechanisms show discrepancies in literature. We hypothesize these issues stem from chaotic processing of the interface.

3. Gaps and Motivation: Why a New Instrument is Necessary

Critical Need: To more accurately determine pure shear and dilatational interfacial kinematics by systematic and controllable processing of interfaces.

Example System: poly(2-ethyl) methacrylate) on air-water interface

Surface pressure-area isotherms on same interface show differences due to types of flow fields during dilatation/compression.

4. Quadrotrough Design

- Elastic band is stretched around four step motors to allow precise interfacial deformation.
- Force balance and Wilhelmy rodplate are used to measure the surface tension at the interface.

5. Impact of Interfacial Processing on Interfacial Structure and Rheology

Systematic processing of the interface allows more accurate decoupling of rheological and thermodynamic contributions for viscoelastic interfaces to determine true rheological parameters.

Model viscoelastic system: stearic acid on 10-3 M alumina nitrate subphase

5.1 Interfacial Processing by Shear

Continuous compression (1 mm/min): rheological and thermodynamic

Stepwise compression: thermodynamic

Shearing: interfacial processing

5.2 Viscoelastic moduli determination

The static ‘thermodynamic’ modulus determined from step compression (67 mN/m) is not a true state variable due to a metastable arrest. Upon shearing, the modulus decreases to 49.3 mN/m, which is the true state of the system.

5.3 Apparent area per molecule (Å2)

6. Conclusion/Future Work

- Pure shear and pure dilation can be achieved through new Quadrotrough instrument to allow processing protocols.
- More accurately determine shear and dilatational rheological parameters and thermodynamic state variables with pure deformations.
- Microstructure determines the macroscopic rheological behavior of viscoelastic interfaces as shown in literature and model stearic acid system.
- Currently, we are also implementing this sample environment on a neutron reflectometer, or rheo-MAGIK, for microscopic structural analysis.

7. Acknowledgements

Credit to funding agencies and collaborators.

Under shear, no breakup of crystalline structure, but evidence shows an image intensity change speculated to be due to amorphous structural rearrangement.