Development of Microrheology Test System for EOR Applications

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Spider Silk

- By weight stronger than steel
- Elongation > 35%
- Degradation products are amino acids
- Low inflammatory response
- Processed into different forms

*Nephilia clavipes*
Golden Orb Weaving Spider
Types of spider silk

The spider uses as many as seven different kinds of silk fiber for various functions.

1) Flagelliform Gland
2) Aggregate Gland
3) Cylindrical Gland
4) Minor Ampullate
5) Anciform Gland
6) Piriform Gland
7) Major Ampullate

Silk Glands

http://www.hyahya.org/themiracleinthespider05.php
Electrospinning Apparatus

- Produces non-woven mats of nanofibers
- Polymers are dissolved in a highly volatile solvent
- Concentration increases viscosity of the spin dope
SEM of Fibers

2400X
12 wt%  14 wt%  16 wt%

20000X

40000X
Advantages of Microrheology

• Performed with small sample volumes
  – ~10’s of microliters
• Provides information on local inhomogeneities
Microrheology in EOR

• Viscoelasticity determination of polymeric and surfactant solutions.
• Evaluation of interfacial dynamics in water-oil systems with and without surfactants and polymers.
• Characterization of small samples of coreflooding experiments for linear viscoelasticity determination and calibration of polymer damage through shearing.
Specific Aims

- **Aim 1**: Develop microrheology capabilities utilizing a model system with polymers in bulk solutions.
- **Aim 2**: Develop interfacial capabilities of the microrheology technique at the oil / water interface.
- **Aim 3**: Validate model system in collaborations
Microrheology set up
Microrheology set up

Schultz and Furst, *Soft Matter*, 2012, 8, 6198-6205
Microrheology set up
Particle issues - Aggregation
Particle Tracking
Mean square displacement is related to the lag time:

\[ \langle \Delta r^2(\tau) \rangle_t \sim \tau^\alpha \]

For purely viscous solutions \( \alpha = 1 \) and the displacement is a linear function of the diffusion coefficient:

\[ \langle \Delta r^2(\tau) \rangle_t = 2nD\tau \]

\( \Delta r \) is the distance traveled

\( n = 1, 2 \) or 3 dimensions
Diffusion

Diffusion can be affected by the temperature, viscosity, and particle size. The diffusion coefficient (D) provides a relationship between these variables. For a spherical particle:

\[ D = \frac{kT}{6\pi \eta a} \]

- \( k \) - Boltzmann constant
- \( T \) - temperature
- \( \eta \) - viscosity of the medium
- \( a \) - size of the particle (radius)
Viscosity Calculation

We used these two equations to calculate the viscosity of the medium,

\[ \eta = \frac{kT q_i \tau}{6 \pi a <\Delta r^2(\tau)>_t} \]

Boltzmann Constant: \(1.3806503 \times 10^{-23} \text{m}^2\text{kg} \cdot \text{s}^{-2}\text{K}^{-1}\)

Particles size: 0.5\(\mu\)m (radius)

Time interval: 5 ms

T: 25°C, 298k
## Results

<table>
<thead>
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*Systematic error.... Why?*
Timeline

• **Technique development.** This will take place during the summer and fall 2012. A presentation of these results will be prepared for the Technical Advisory Board meeting in the fall semester 2012.

• **Bulk rheological properties (Aim1).** This will initiate after the initial technique development has matured enough to test polymeric solutions. Fall 2012-Spring 2013.

• **Interfacial Rheology (Aim 2). Spring 2013-Fall 2013.** This stage requires resolving characterization of oil fluorescence.

• **Validation of model systems (Aim 3).** This task will involve bulk properties as well as interfacial measurements. Late Fall 2012 – End of Spring 2014. Most of the experiments for evaluation of EOR formulations will take place between the second semester of 2013 and the first semester of 2014.
Acknowledgements

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• Collaborators – Vladimir Alvarado
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