MULTIPLE PARTICLE TRACKING MICRORHEOLOGY

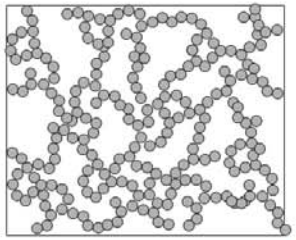
P. Nguyen (BAA&S) and E. Furst

University of Delaware • Center for Composite Materials • Department of Chemical Engineering

Introduction

Colloidal Gels

- Simply known as Gels
- A semi-solid colloidal material which consists of solid dispersed in liquid
- Possess both viscous and elastic properties
- Forms an fractal network that holds the liquid within its structures over time



Microrheology

- Micro-spherical probe particles are suspended in the colloidal gel system and their motion is studied
- Relates MSD, $<\Delta r^2(t)>$, of colloidal particles to the linear viscoelastic properties of material
- Probes very localized mechanical properties using tracer particles embedded in a complex fluid
- Particle motions can be interpreted in terms of the local viscoelastic properties of the surrounding medium
- Macroscopic Bulk Modulus can be obtained

Tracer particles embedded in a Gel network

- Purely viscous fluids:

$<\Delta r^2> = 2nDt$

$D = k_B T/6\pi\eta a$ (Stokes-Einstein Equation)

Microrheology Techniques and Assumptions

- There are wide range of techniques to get MSD of particle tracking such as:
  - »Dynamic Light Scattering
  - »Diffusive Wave Spectroscopy
  - »Epifluorescence Microscopy ← Used in these experiments
- The assumptions involved in these experiments are:
  - » The implanted tracer particles to be non-interacting with the surrounding medium
  - » The size of the probe particles larger than the characteristic length scale of the microstructure being investigated
  - » The tracer particles do not affect the existing microstructure of the complex fluid in which they are dispersed
  - » The Generalized Stoke-Einstein Relationship is valid

Project

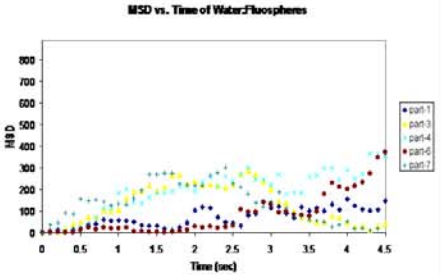
- Investigating the structural and mechanical properties of the organogel, BYK-410

Experimental Procedure

- Dilute 0.05 wt% of Fluospheres with Milli-Q – distilled water
- Track particles using Labview
- Use Scion Imaging and IDL program to obtain the MSD of the particles

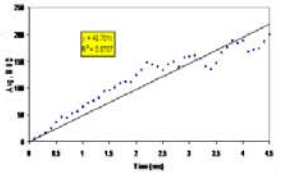
A typical fluorescent image

Experimental Procedure



Viscosity of Water

- Carboxylate-Modified Fluorescent Microspheres
  - Diameter = 1.0 μm
  - Poly-dispersed



$\eta = 4k_B T t / 6\pi a <\Delta r^2>$

$a = 1.0\ \mu m$

Calculated: η = 0.78cp

literature → 0.89 cp @ 25 C

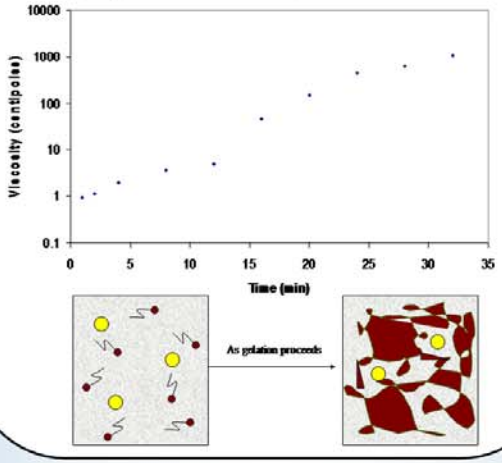
Difference is due to possible sedimentation

Organogel Investigation

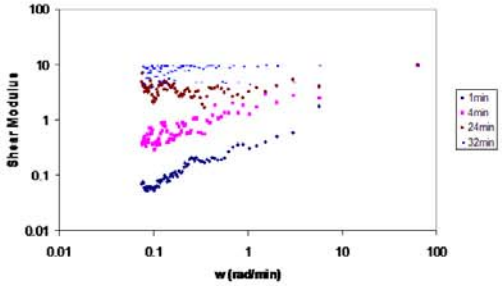
- **BYK-410** – a liquid rheological additive for solvent-based and solvent-free coatings that contains 49.5% **organogel**
- Used **Polybead Carboxylate Microspheres** as solid particles
  - »Diameter = 3.0010 μm
  - »Less aggregation
  - »Mono-dispersed
- Mixed with **Butylcellosolve** ($C_4H_8OHC_2CH_2OH$)

Organogel Gelation Dynamics

$\eta = 4k_BT\tau/6\pi a\langle\Delta r^2\rangle$ •Viscosity increases with time

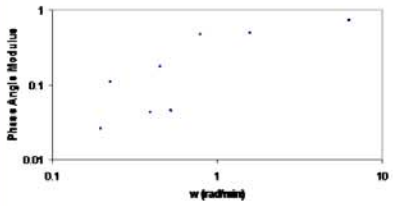


Shear Modulus Analysis



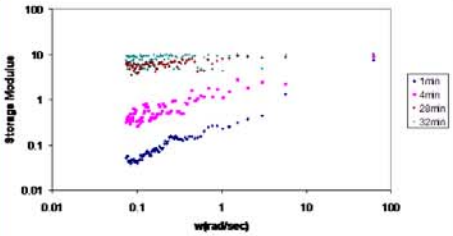
$G_d(\omega) \sim \langle\Delta r^2(t)\rangle^{-1}_{t=2\pi/\omega}$

Phase Angle Modulus Analysis



$\delta(\omega) \sim [\, d \ln G_d / d \ln t \,]_{t=2\pi/\omega}$

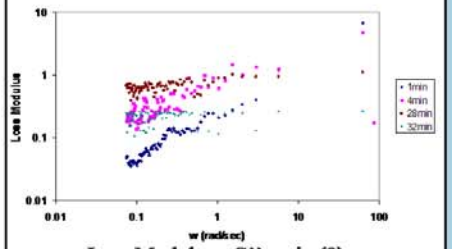
Storage Modulus



$G'(\omega) + iG''(\omega) = G_d(\omega)\, e^{i\delta(\omega)}$

Storage Modulus : $G' = \cos(\delta)$

Loss Modulus



Loss Modulus : $G'' = \sin(\delta)$

Conclusions

- The sample gels up in approximately 30min with 3% of organogel according to the viscosity plot
- Viscosity increases with time
- Shear and Phase Angle Modulus increase with time
- Storage and Loss Modulus increase with time

Acknowledgements

This work is supported by the Army Research Laboratory through the Composite Materials Research program.