Nanoscale Directed Self-Assembly in Electrical and Optical Fields

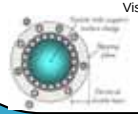
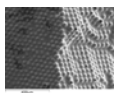
NSF NIRT Grant CTS-0506701 (2007)

N.J. **Wagner**, E.W. **Kaler**, E.M. **Furst**, Chemical Engineering, University of Delaware, Newark, DE 19716,
O. **Velev**, Chemical Engineering, North Carolina State Univ. J.F. **Brady**, Chemical Engineering, California Inst. Tech

Directed Self Assembly (DSA) : Motivation

Vision2020 Chemical Industry R&D Roadmap for Nanomaterials by Design[1] targeted key areas for investment in research that are expected to be critical for the development of emerging nanotechnologies. It defined **Nanomaterials by Design** as "The ability to employ scientific principles in deliberately creating structures with nano-scale features (e.g., size, architecture) that deliver unique functionality and utility for target applications." Critical areas requiring the most immediate research attention include robust, controllable, and scalable methods for assembly of functional nanoparticle "building blocks" into devices with emergent properties of technological interest. To directly address these core issues in nanotechnology and **nanomanufacturing**, we have assembled a team composed of experimentalists and theoreticians/modelers to develop a scientific knowledge base critical for the successful development of nanotechnological devices based on **directed self-assembly (DSA).**

(1) http://www.chemicalvision2020.org/nanomaterialsroadmap.html "Chemical Industry R&D Roadmap for Nanomaterials By Design: From Fundamentals to Function", Chemical Industry Vision2020 Technology Partnership, (2003)

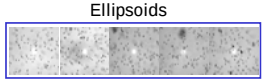

DEP Cell and Ellipsoids in Electric Fields

Novel Materials by DEP

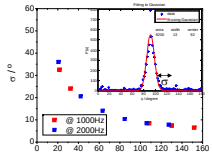
Design of a DEP Cell in a Microscope Stage

Features:
- Reproducible cell assembly
- 6 separately addressable electrode leads
- sample feeds from the top
- Lithographed electrodes on bottom slide
- Temperature control

Ellipsoids

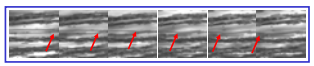


Increasing field strength



At low volume fractions ellipsoids orient with the field direction. The orientation mainly depends on field strength

Spheres



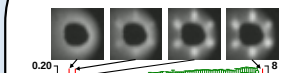
Increasing time

Experiments with 3μm PS spheres in the DEP cell revealed interesting zipper effect between two chains at field strength of 150Vcm^{-1}.

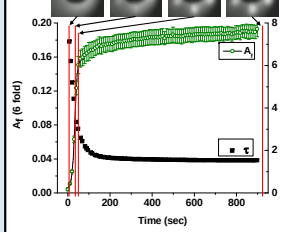
Future Work

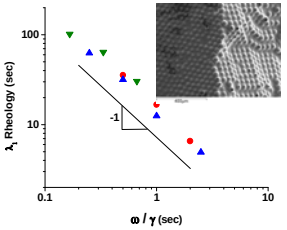
Exploring different particles shapes, sizes and dielectric properties using TiO2 ellipsoids, zeolites, precipitated calcium carbonates (PCC) and PS ellipsoids with different aspect ratios.

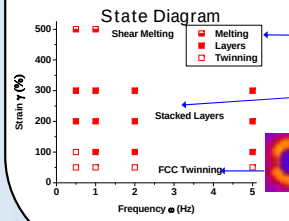
Directed Ordering of Particles with Shear Fields

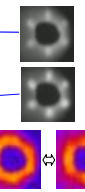


$$y = y_1 e^{-x/\lambda_1} + y_2 e^{-x/\lambda_2}$$









- Dynamics of shear ordered systems are seen with either rheological or scattering measurements
- Both HCP and FCC ordering is observed
- Scaling follows $\lambda_1 \propto \omega\gamma^{-1}$
- Shear ordering is applicable over a range of particle sizes
- SEM directly observes shear ordered structures

McMullan J.M. and Wagner N.J. "Directed Self-Assembly of Suspensions by Oscillatory Shear Flow" *JoR*, in preparation.

Broader Impacts: Outreach

Short Course on Directed Self Assembly

2007 Short Course on Directed Self Assembly was held in conjunction with the 81st ACS Colloid Symposium at the University of Delaware.

- **Introduction & Background** - Norman J. Wagner
- **Self-Assembly** - Eric W. Kaler
- **Colloidal Interactions and Directed Self-assembly under Electrical Fields** - Orlin D. Velev
- **Optical Tweezers** - Eric M. Furst
- **Micromechanics of Colloidal Suspensions** - John F. Brady

Lecture NOTES are available online:
www.nirt.che.udel.edu/

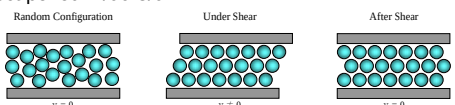
Broader Impacts: Collaborations

Sandia National Laboratories:

"Optical Trapping for Directed Self-Assembly":
Amount: $375,000
Project period: 3/1/07-2/28/10:
The project is a NINE LDRD with Anne Grillet as the program director and Dan Rader as program manager.
Strategic partners include Eric Dufresne, Yale University.

Rohm & Haas Electronic Materials:

"Shear Ordering of Concentrated Particle Suspensions" Amount: $40,000
Project period: 7/06-8/07

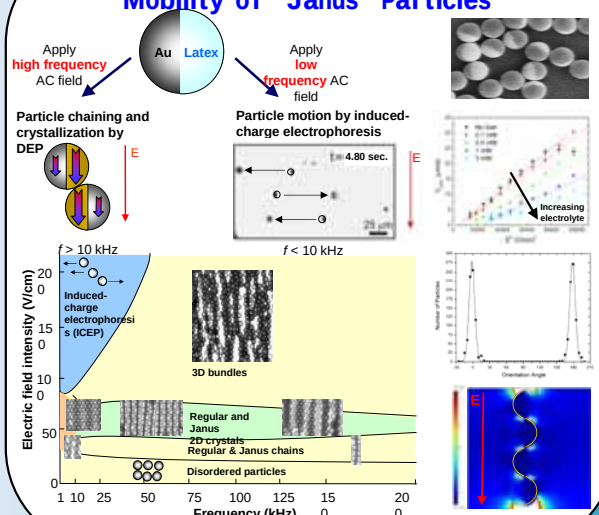


For more information, including publications,

www.nirt.che.udel.edu/

NJ Wagner wagnernj@udel.edu

DEP Assembly and Electrohydrodynamic Mobility of "Janus" Particles



S. Gangwal, O. J. Cayre, M. Z. Bazant, O. D. Velev, "Induced-charge electrophoresis of metallo-dielectric particles," Phys. Rev. Lett., submitted (2007).