SELF-ASSEMBLY AND DYNAMICS OF ANISOTROPIC COLLOIDS

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BY

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THESIS

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Abstract

This work details the development of techniques to fabricate and study structured colloidal particles...

To Leigh.

Acknowledgements

Table of Contents

List of Figures

Chapter 1

Introduction

- **Motivation**
  - Colloidal materials are important because of x, y, and z.
  - Limited assembly mechanisms available for conventional spherical particles. (Figure: crystal, gel, glass graphics)
  - Desirable to produce self-assembled structures which have different types of order.
  - One way to do this: fabricate anisotropic colloids which naturally assemble in a different fashion.
- **Broad Description**
  - Fabricated polymer colloids with shape and chemical anisotropy.
  - Specifically: rods with various aspect ratios, and Janus rods.
  - Also fabricated two-patch rods and more complex geometries.
  - Wrote tracking software for rods
  - Wrote tracking software for complex geometries (drop this if needed)
  - Measurement of two-dimensional dynamical behavior by time-series fluorescence/confocal microscopy.
  - Particle tracking to measure translational and rotational diffusion of particles.
  - Also fabricated microfluidic devices to study confined particles (appendix)
  - Also developed grayscale techniques to produce particles with controllable height (appendix)

Chapter 2

Literature Review

2.1 Anisotropic and Patchy Colloids

2.2 Fabrication of Janus Colloids

2.3 Flow Lithography

2.4 Particle Tracking

Chapter 3

Computerized Tracking of Anisotropic Colloids

3.1 Introduction

- Desirable to locate anisotropic particles in microscopy images to study dynamics and assembly.
- Previous work in this area: Crocker and Grier, Solomon
- Can't use Solomon method: fluorescence is too flat for SFL particles. 2D-extruded objects. (Figure to illustrate.)
- Must develop new algorithms which can work on these particles.

3.2 Algorithms

- Tracking algorithm for rods
  - Image cleanup using erosion, opening
  - Particle segmentation using watershed transform
  - Particle skeleton (backbone) using distance transform plus rank-order filter
  - Calculation of center-of-mass, oritentation according to Solomon
  - Time-series tracking according to Blair and Dufrense
  - Difference between 2D and 3D version of algorithm
- Tracking algorithm for arbitrary shapes
  - Initial steps same as for rods: cleanup, segmentation
  - "Skeletonization" as above, but producing a more complex skeleton than for rods
  - Calculate center-of-mass as with rods
  - Choose a sample skeleton as the "canonical" particle skeleton

  - Isolate particles into individual windows
  - To measure orientation: rotate canonical skeleton image in small increments. For each one, AND together the rotated skeleton and the sample skeleton. Maximize pixel sum of ANDed image.
  - Faster in 2D than in 3D
  - Implementation not finished!

3.3 Implementation

- Rod tracking implemented in 2D in Matlab.
- Go over the details of the matlab implementation
- Rod tracking implemented in 3D in Matlab, but with major bugs.
- Arbitrary tracker not yet fully implemented, using Matlab.

3.4 Assessment

- Identify issues caused by morphological image processing for these algorithms.
- Estimate errors in particle segmentation
- Estimate error of rod COM and orientation calculations.
- Estimate error of skeleton-based orientation calculations.

Chapter 4

Assembly and Dynamics of Rod-Shaped Colloids

4.1 Introduction

- Natural rod systems
- Systems studied by Solomon
- Janus colloids: Granick
- Interest in Janus rods

4.2 Experimental Procedure

4.2.1 Stop-Flow Lithography

- Microscope setup
- Pressure system–Rob
- LabView controller for SFL
- Design of microfluidic devices for up to 3-stream SFL
- Fabrication of microfluidic devices

4.2.2 Mask Design

- Demagnification using 60X objective
- Design parameters
- Rod aspect ratios used

4.2.3 Particle Collection

- Considerations for collection
- Solvents used
- Pipettes
- Fluorosilane coatings

4.2.4 Diffusion Measurements

- Confocal microscopy setup
- Space and time resolution requirements
- Fluorescence requirements

4.3 Results and Discussion

4.3.1 Resolution

- Limiting factors for SFL resolution: mask design, optics, flow effects
- Resolution limits constrained by 60X lens–need to redo this (1 hour work)
- Resolution limits for Janus rods–interface effects

4.3.2 Translational and Rotational Diffusion

- Particle collection–PEGDA vs TMPTA
- Compare particle/solvent/surface effects
- 2D diffusion size series: TMPTA in toluene (additional experiments may be required)
- Analyze diffusion data for rods (partially done).

4.3.3 Self-Assembly of Janus Rods

- Fabrication of Janus rods: various sizes (figure)
- Comparison of self-assembly in various solvents (figure)

- Small clusters vs large structures
- Alignment of assembled rods
- Image segmentation for analyzing structures
- Some more images may be required

Chapter 5

Assembly and Dynamics of Exotic Colloids

5.1 Introduction

5.2 Experimental Procedure

5.2.1 Device Design

5.2.2 SFL with Multiple Co-Flowing Streams

5.2.3 Mask Design

5.2.4 Particle Collection

5.3 Results and Discussion

5.3.1 Diffusion Measurements

5.3.2 Self-Assembly

Chapter 6

Conclusions

6.1 Future work

Appendix A

Microfluidic Devices for Studying Self-Assembly

A.1 Introduction

A.2 Experimental Procedure

A.2.1 Device Design and Fabrication

A.2.2 Proposed Protocol

A.3 Results and Discussion

A.3.1 Fabrication

A.3.2 Particle collection

A.3.3 Solvent exchange

A.3.4 Challenges

Appendix B

Grayscale Stop-Flow Lithography

B.1 Introduction

B.2 Experimental Procedure

B.2.1 Design of Grayscale Filters

B.2.2 Grayscale Stop-Flow Lithography

B.3 Results and Discussion

B.3.1 Intensity Reduction

B.3.2 Particle Size Reduction

B.3.3 Particle Swelling Issues