PROGRAM

May 13th 2010

4th South-East

Workshop on

Soft Materials

Dan Goldman and Elisa Riedo

Our Sponsors:

Program

4th South-East Workshop on Soft Materials and Interfaces
Georgia Institute of Technology – Emory University
May 13, 2010

MoSE Building on Georgia Institute of Technology Campus
(Molecular Science and Engineering)

Registration, Breakfast, and Breaks: **G011**
Lunch: 1st Floor **Atrium**
Seminars: Ground Floor Room G011

8:30 AM - 9:00 AM
Breakfast and Registration, Ground Floor G011

9:00 AM - 9:05 AM
Welcome from Dan Goldman, Ground floor G011

Morning Invited Speakers (Chair: Elisa Riedo)
9:05 AM - 9:50 AM
Paul Chaikin, Department of Physics, New York University
Self-Replication Without Life

9:50 AM - 10:35 AM
Laura Finzi, Department of Physics, Emory
The Physics Behind the Many Strategies of the Lambda Repressor to Maintain Lysogeny

10:35 AM - 10:50 AM
Coffee, Ground Floor G011

10:50 AM - 12:15 PM
Sound Bites I: Nano and Colloidal Matter
Chair: Sven Behrens

Gary Hunter, Emory
Influence of Boundary Mobility on the Dynamics of Confined Colloidal Suspensions
Eric Weeks, Emory
Experimental Study of Random Close Packing

James Sebel, Emory
Interfacial Rheology Using a Magnetic Needle Viscometer
Adriana San Miguel, Georgia Tech
Responsive Colloidosomes: Triggered Dissolution and Tunable Permeability
Hongzhi Wang, Georgia Tech
Prepare Robust and Smart Colloidsome Capsules by Double Emulsion
Qiong Guo, Georgia Tech
Particle Charging in Nonpolar Liquids by Nonionizable Surfacatants
Carlos Espinosa, Georgia Tech
Interaction of Charged Colloidal Particles in Nonpolar Liquids
Joaquim Clara-Rahola, Georgia Tech
Phase Behavior of PNiPAM-PEG Microgel Suspensions
Juan Jose Lietor-Santos, Georgia Tech
The Role of Particle Softness in the Phase Behavior of Microgel Suspensions
Sharan Devaiah, Georgia Tech
Topological Defects on Ultrathin Shells of Nematic Liquid Crystals
Hassan Masoud, Georgia Tech
Transport Through Random Polymer Networks in Tension
Xuxia Yao, Georgia Tech
Studies on Lyotropic Chromonic Liquid Crystals
Hamdi Torun, Georgia Tech
Analysis of Frequency-dependent Viscous Damping for Micromachined Membranes in Viscous Fluid
Haskell Beckham, Georgia Tech
Dynamics in Soft Materials by NMR Relaxometry and Diffusometry
Connie Roth, Emory
Effect of Free Surface on Physical Aging of Polystyrene Films and Its Connection to Glass Transition Temperature Reductions: Evidence for a Gradient in Dynamics
Andy Pahner, Emory
Physical Aging Rates of Thin Polystyrene Films: Effect of In-Plane Stress during Free-Standing Quench
Annika Kriisa, Emory
Characterizing Phase Separation of PS/PVME Blends Using Different Fluorophores
Hsiang-Chih Chiu, Georgia Tech
Hindered Rolling and Friction Anisotropy in Supported Carbon Nanotubes
Suenne Kim, Georgia Tech
Direct Writing and Characterization of Poly(p-phenylene vinylene) Nanostructures
Debin Wang, Georgia Tech
Nanoscale Tunable Reduction of Graphene Oxide for Graphene Electronics
Keith Carroll, Georgia Tech
Thermochemical Nanolithography: Applications and Capabilities

12:15 PM - 1:30 PM
Lunch and Discussion, MoSE Building, First Floor Atrium

Afternoon Invited Speakers (Chair: Eric Weeks)
1:30 PM - 2:15 PM
Alberto Fernandez-Nieves, School of Physics, Georgia Tech
Order Meets Topology: Nematics on Curved Spherical Spaces

2:15 PM - 3:00 PM
Marta Dark McNeese, Department of Physics, Spelman College
Undergraduate Physics Research in Soft Matter at Spelman College: Knee Cartilage and OLED's

3:00 PM - 3:15 PM
Coffee and Cookies, Ground floor G011

3:15 PM - 4:15 PM
Sound Bites II: Biological Matter
Chair: Victor Breedveld

Sachin Goyal, Emory
Continuum Modeling of DNA
Qing Shao, Emory
Effects of Spermine on DNA Supercoiling and Duplex Stability
Tung Le, Georgia Tech
Reentrant DNA Condensation by Multivalent Counterions
Vikram Prasad, Georgia Tech
Rheology of Algae Suspensions
Kyung Duk Koh, Georgia Tech
Detection and Quantification of Ribonucleotides Embedded into DNA
James Hardin, Georgia Tech
Controlled Release of DNA from Gelatin Blocks and Microspheres
Sven Behrens, Georgia Tech
Prediction and Accelerated Test of Protein Aggregation
Ryan Maladen, Georgia Tech
Principles for Undulatory Swimming in Granular Media
Jan Krajniak, Georgia Tech
Developmental Studies of Higher Organisms
Jeffrey Stirman, Georgia Tech
Spatial and Temporal Optical Activation of Neurons in Freely Behaving Worms
Hyewon Lee, Georgia Tech
Understanding Environment-responsive Transcriptional Regulation in C. elegans Using Microfluidic System
Sharon Hamilton, Georgia Tech
Progress Towards Tunable Hydrogel Co-Culture Systems
Taymour Hammoudi, Georgia Tech
Hydrogel Biomaterials for Stem Cell Co-Culture and Study of Cellular Crosstalk

Harold Kim, Georgia Tech
How DNA Packaging Influences Genetic Code Processing
Gabriel Mitchell, Georgia Tech
Quantifying Enzymatic Lysis by Combining Theoretical and Experimental States of Information

4:15 PM - 4:25 PM
Coffee, Ground Floor G011

4:25 PM – 5:15 PM
Sound Bites III: Fluid and Granular Matter
Chair: Connie Roth

Venkata Gundabala, Georgia Tech
Current-voltage Characteristic in Electro-Coflow
Ekapop Pairam, Georgia Tech
Growth and Collapse, an Evolution of Fat Toroidal Droplets
Ivan Caceres, Georgia Tech
Rapid Phenotyping and Visual Screens Enabled by Microfluidics
Alison Hirsch, Georgia Tech
Particle Behavior in Microfluidic Mixers: Experiments and Modeling
Edward Park, Georgia Tech
Microfluidics - Complex Microenvironments for Cell-Based Assays
Fengshou Zhang, Georgia Tech
Fluid Injection into Granular Media in Hele-Shaw Cells
Yang Ding, Georgia Tech
Drag Induced Lift in Granular Media
Nick Gravish, Georgia Tech
Flow and Fracture in Granular Media
Kenneth Desmond, Emory
Force Chains & Granular Temperature of 2D Frictionless Emulsion Droplets
Dandan Chen, Emory
Observing Rearrangements in a 2D Emulsion Flowing Through a Hopper
Laura Golick, Emory
Deformation of Quasi-2D Oil-in-Water Emulsions
Xia Hong, Emory
Jamming of Oil in Water Emulsion Flow in a 2D Hopper

Title and Abstracts:

Invited Speakers:

Paul Chaikin, Centre for Soft Condensed Matter Research, Physics, NYU

"Self-Replication Without Life"

We want to make a "non-biological" system which can self-replicate. The idea is to design particles with specific and reversible and irreversible interactions, introduce seed motifs, and cycle the system in such a way that a copy is made. Repeating the cycle would double the number of offspring in each generation leading to exponential growth. Using the chemistry of DNA either on colloids or on DNA tiles makes the specific recognition part easy. In the case of DNA tiles we have in fact replicated the seed at least to the third generation. The DNA linkers can also be self-protected so that particles don't interact unless they are held together for sufficient time – a nano-contact glue. We have also designed and produced colloidal particles that use novel "lock and key" geometries to get specific and reversible physical interactions.

Laura Finzi, Department of Physics, Emory

"The Physics Behind the Many Strategies of the Lambda Repressor to Maintain Lysogeny"

The lambda bacteriophage epigenetic switch determines the growth lifestyle (lysogeny vs. lysis) of the virus after infection of its host (*E. coli*). It is now clear that the switch consists of a ~2.3 kbp-long DNA loop mediated by the lambda repressor protein. Using tethered particle microscopy (TPM), magnetic tweezers and AFM, our laboratory has novel, direct evidence of loop formation and breakdown by the repressor, the first characterization of the thermodynamics and kinetics of the looping reaction and its dependence on DNA supercoiling and repressor non-specific binding. These *in vitro* data provide insight into the lambda repressor-mediated looping mechanism which leads to predictions for that *in vivo*. The significance of this work consists not only in the new insight into a paradigmatic epigenetic switch that governs lysogeny (quiescence) vs. lysis (virulence), but also into the detailed mechanics of regulatory DNA loops mediated by multi-protein complexes.

Alberto Fernandez-Nieves, School of Physics, Georgia Tech

"Order Meets Topology: Nematics on Curved Spherical Spaces"

When nematic liquid crystals are confined to spherical shells, complex defect structures emerge. These structures are characterized by a varying number of point defects and disclination lines, depending on the elastic energy of the liquid crystal, the thickness of the shell, and the boundary conditions for the director at the confining spheres. Topology establishes restrictions that must be fulfilled, but it is the energy landscape of the ordered material what ultimately determines the final state of the system. By using double emulsion drops, we can experimentally address this interplay between topology and energy. We find a wealth of defect structures in our shells and propose that the shell thickness inhomogeneity is the key parameter enabling the broad range of configurations we observe; these include long-time predicted configurations [T.C. Lubensky, J. Prost, J. Phys. II France 2, 371 (1992)], as well as new structures and transitions between them that where never considered before. In addition, we hope to extend our studies to non-spherical surfaces, such as the torus and higher-genus surfaces. For this purpose, we have recently generated toroidal droplets and have studied their hydrodynamic stability. On these closed surfaces, the nature of the defect structure is expected to be qualitatively different from that of the spherical case.

Marta Dark McNeese, Department of Physics, Spelman College

"Undergraduate physics research in soft matter at Spelman College:
Knee cartilage and OLED's"

Research activity in the Physics Department at Spelman College on soft matter includes the study of laser interactions with soft fibrocartilage of the knee, as well as optical properties of organic molecules. These activities have involved undergraduate STEM majors at Spelman of all levels. Laser welding of soft bovine knee tissue is a research project underway at Spelman College. Infrared laser light (wavelength = 1064 nm) from a diode-pumped solid-state laser is used to weld tears in bovine ligament and meniscus. A protein-based glue is applied to the tissue as a means to enhance the laser heating effect. The absorption of a continuous wave laser irradiation by biological tissue adds heat to the tissue, and results in a temperature increase. With temperature increases that are high enough to allow welding of the tissue, currently we also see significant thermal damage in surrounding tissue. Recently we have begun a new study investigating benzimidazoles as photovoltaic and light-emitting materials. This talk will include a brief summary of this project and the status of synthesis of these molecules.

Sound Bites I: Nano and Colloidal Matter

Gary Hunter, Emory

"Influence of Boundary Mobility on the Dynamics of Confined Colloidal Suspensions"
We use fast confocal microscopy to study the influence of interfacial mobility and confinement on the dynamics of dense colloidal suspensions. Experiments on confined molecular super-cooled liquids have shown that hard/immobile boundaries result in an increase in relaxation times relative to bulk measurements, whereas soft/mobile boundaries lead to a decrease in relaxation times. We confine suspensions of PMMA microspheres within emulsion droplets of different sizes, thereby probing the consequences of confinement. By changing the viscosity of the external, continuous phase, we also control the interfacial mobility of our samples. In this way, we separate the two effects and draw comparisons between mobility within colloidal suspensions and molecular liquids.

Eric Weeks, Emory

"Experimental Study of Random Close Packing"
A collection of spherical particles can be packed tightly together into an amorphous packing known as "random close packing" (RCP). This structure is of interest as a model for the arrangement of molecules in simple liquids and glasses, as well as the arrangement of particles in sand piles. We use confocal microscopy to study the arrangement of colloidal particles in an experimentally realized RCP state. We image a large volume containing more than 500,000 particles with a resolution of each particle position to better than 0.02 particle diameters. While the arrangement of the particles satisfies multiple criteria for being random, we also observe a small fraction (less than 3%) of tiny crystallites (4 particles or fewer). These regions pack slightly better and are thus associated with locally higher densities. Detailed analysis suggests that there are long wavelength density fluctuations in our sample, perhaps due to the tiny crystallites. Our results suggest that experimentally realizable RCP systems may be different from simulated RCP systems, in particular, with the presence of these long wavelength density fluctuations.

James Sebel, Emory

"Interfacial Rheology Using a Magnetic Needle Viscometer"
We are building a magnetic needle viscometer to probe the viscoelastic properties of thin films. Our apparatus will employ Helmholtz coils to control the position and orientation of a magnetic needle suspended in the film. By driving the needle we can induce an in phase and out of phase response in the film allowing us to probe the viscoelastic properties of the material. The experimental apparatus will be constructed in such a way that both local and bulk properties of the film are accessible. The primary applications for our device will be to quantify the local and bulk rheology of films that have spatially heterogeneous properties.

Adriana San Miguel, Georgia Tech

"Responsive Colloidosomes: Triggered Dissolution and Tunable Permeability"
Microencapsulation techniques have become increasingly important as an advanced formulation tool with widespread applications in the preparation of functional materials, chemically or biologically active agents, pharmaceuticals, cosmetics, food, and especially as drug delivery agents and cell carriers. One novel technique for encapsulation relies on solid-stabilized emulsions, so-called "Pickering emulsions", as a template for capsule formation: colloidal particles adsorbed to emulsion droplets are connected into a solid shell enclosing the droplet. The resulting microcapsules, whose shell is composed of solid particles, are known as colloidosomes. Ideally, such capsules should retain and protect an encapsulated agent until delivery conditions are reached in the target environment. Release could be triggered by an external disruption of the system or ideally by a change in the inherent conditions of the delivery medium, such as its temperature, pH, or salinity.
We have developed Pickering emulsion-based microcapsules that dissolve rapidly upon a pH change under mild solution conditions. These capsules combine the sturdiness and pore size control of colloidosomes with the option of triggered disassembly known from stimulus-responsive Pickering emulsions. This work reports the assembly of pH-responsive microcapsules from double Pickering emulsions. The double emulsions are stabilized with nanoparticles, which have been prepared by nanoprecipitation ("Ouzo Effect"). The microcapsules dissolve upon a slight pH change at mild solution

conditions. Evidence of this triggered response is provided in micrographs demonstrating a fast and complete dissolution of the microcapsules. The permeability of the capsule shell is quantified using Fluorescence Recovery After Photobleaching (FRAP). The work currently under development focuses on tuning the capsule permeability by the addition of a polymer in the middle phase of the double emulsion. With this approach, responsive colloidosomes with a desired permeability can be obtained.

Hongzhi Wang, Georgia Tech

"Prepare Robust and Smart Colloidsome Capsules by Double Emulsion"

The colloidsome capsule with robust and smart characteristics is our focus. By double emulsion, the thickness of colloidsome shell could be controlled to enable the capsules having enough strength to undertake pressurized environment. Meanwhile, ph or temperature response polymer particles are incorporated to make the capsules look smart, with controllable release as ph or temperature varies. This desirable capsules are anticipated their role of encapsulating active contents and controlling its release. As such, some potential applications may be exploited in flexographic printing, water treatment, drug delivery etc.

Qiong Guo, Georgia Tech

"Particle Charging in Nonpolar Liquids by Nonionizable Surfacatants"

Non-polar liquids do not easily accommodate electric charges, but ionic surfactant additives are found to help raise the conductivity and stabilize the immersed solid surfaces. They avoid the large energetic barrier associated with the introduction of small ions in low dielectric media by forming charged micellar aggregates. Here, we study the rarely considered charging effects induced by surfactant molecules without ionizable groups, sorbitan oleate. The behavior that non-ionizable surfactants induce charge in nonpolar oils can be explained by charge disproportionation of molecular surfactant complexes in the sub-CMC regime and reverse micelles above the CMC. Electrokinetic studies of added colloidal particles further exhibit the micelles' ability to create and screen electric charges on the surface of suspended solid particles. Strong particle-charging effects and charge screening are found even at surfactant concentrations below the critical micelle concentration. Our findings suggest that nonionic surfactants can play a key role in the industrially important task of controlling charges in non-polar solvents.

Carlos Espinosa, Georgia Tech

"Interaction of Charged Colloidal Particles in Nonpolar Liquids"

The interaction of charged colloidal particles in non-polar oils is investigated. The controversial proposition that particles can sustain electric surface charges on the surface portion in contact with the oil phase is evaluated. This notion is supported by liquid-structure analysis of 2-D particle ensembles observed with digital video microscopy. Interaction measurements in the presence of surfactant micelles in the oil phase in fact suggest the surprising possibility of screening electrostatic interaction in oils with the help of non-ionic surfactants.

Joaquim Clara-Rahola, Georgia Tech

"Phase Behavior of PNiPAM-PEG Microgel Suspensions"

We study aqueous suspensions of temperature responsive Poly(N-isopropylacrylamide) (PNiPAM) microgels cross-linked with Poly(ethylene Glycol) (PEG). We find that in contrast with other cross-linkers, the properties of PEG at different temperatures results in an unusual intra-particle configuration that guarantee a repulsive interaction between particles throughout the spanned temperature range of 10C ≤ T ≤ 40C. We also focus the dynamic and mechanical properties of PNiPAM-PEG microgel suspensions as a function of temperature at volume fractions above 1. Interestingly, If we remain at a fixed volume fraction we find dramatic changes in comportment at different temperatures. As a result, the phase behavior of these systems also changes and it exhibits analogies and mark differences with hard sphere behavior.

Juan Jose Lietor-Santos, Georgia Tech

"The Role of Particle Softness in the Phase Behavior of Microgel Suspensions"

Microgels are colloidal systems made of crosslinked-polymeric networks immersed in a solvent, whose size can be controlled through external stimuli such as temperature, pH or light. Its intrinsic elasticity allows microgel suspensions to show a wealth of different behaviors as opposed to hard spheres in which liquid, crystal and glassy phases are observed depending solely on the volume fraction of the particles. We study the phase behavior of microgel suspensions varying the volume fraction of the system by using the swelling properties of the particles, which we tune using hydrostatic pressure; the use of pressure allows fast particle size changes that occur homogeneously throughout the sample. To characterize the structural and dynamical properties of the system we use Light and Small Angle Neutron Scattering. We observe formation of crystal and glassy phases, reminiscent of the behavior of colloidal hard spheres.

However, our data seems to suggest that the suspension polydispersity changes with particle volume fraction; through these changes, the system manages to crystallize and forms glasses with unusual structural features.

Sharan Devaiah, Georgia Tech

“Topological Defects on Ultrathin Shells of Nematic Liquid Crystals”

Nematic Liquid crystals [NLC] are rod like molecules that in the absence of external influences arrange themselves parallel to each other and hence tend to point in a given direction. The average orientation of these molecules is given by the director,n, which is essentially a bi-directional vector which quantifies the orientation of the molecules in a given region of the sample. When NLCs are confined to a curved surface, the geometrical constraints imposed by the surface causes a distortion in the molecular orientation. In certain regions, the molecular orientation is such that the director cannot be defined. Such regions are called topological defects. Theory had predicted that the ground state of NLCs confined to a bidimenensional sphere has four defects located at the vertices of a tetrahedron. The tetrahedral defect structure is of great interest in material science because defects in NLCs are regions that can be functionalized to serve as 'bonds' that could pave the way for making macroatoms with tetrahedral bonding properties similar to sp3 hybridized atoms like Carbon. By using ultrathin shells of NLCs, we show that the tetrahedral structure is indeed what we observe experimentally for ultrathin nematic shells, verifying the theory for the first time.

Hassan Masoud, Georgia Tech

“Transport through Random Polymer Networks in Tension”

Random networks of elastic material, such as polymer gels and cytoskeletal structures, are frequently found in synthetic and biological materials. Transport properties, i.e. permeability and diffusivity, of these networks have always been of interest to physicists and biologist. However, due to the geometrical complexities and insufficient computational power in the past, there is little work on 3D simulation of the transport through these kinds of disordered networks. Here, using two mesoscopic simulation methods, we study permeation, self-diffusion, particle diffusion and chain diffusion through these networks. We further quantify the dependence of these transport properties on network geometry both when network is unstressed and when it is under mechanical deformation. The mesoscopic methods used are as follows: 1) Bond-bending lattice spring model (LSM) that captures the elastic behavior of the network and the chain. 2) Dissipative particle dynamics (DPD) that explicitly takes into account viscous fluid and its interactions with the network and diffusive objects. Findings of this work have applications in different areas including drug delivery, paper manufacturing, tissue engineering and physiological systems and processes.

Xuxia Yao, Georgia Tech

“Studies on Lyotropic Chromonic Liquid Crystals”

Lyotropic chromonic liquid crystals (LCLCs) have gained increasing attention in the last two decades as an interesting but still poorly understood class of lyotropic liquid crystals. LCLCs consist of many dyes, drugs, nucleic acids, antibiotics, carcinogens and anti-cancer agents. Applications of LCLCs have been explored as polarizers,optical compensators and biosensors. Our studies
mainly focus on the phase behavior, aggregation structures, alignment techniques, defect dynamics and exploration of new applications of LCLCs.

Hamdi Torun, Georgia Tech

“Analysis of Frequency-dependent Viscous Damping for Micromachined Membranes in Viscous Fluid”

Fluid damping on a micro-device oscillating in fluid determines its dynamics and noise characteristics. There is a strong need to model fluid damping accurately especially for devices operate near their thermal noise levels. We have developed a model based on finite-element modeling (FEM) to predict fluid damping on a micromachined membrane-based force sensor. This model is used to solve Navier-Stokes equations for membrane-fluid interactions. Then, frequency-dependent viscous damping due to hydrodynamic drag force on the membrane is extracted. Calculating viscous damping without the need for a fitting parameter allows us to generate thermal noise spectra of the sensors prior to any experimental characterization. We present our model along with the experimentally obtained noise spectra of the sensors. Model predictions compare well with the experimental data, validating our model.

Haskell Beckham, Georgia Tech

“Dynamics in Soft Materials by NMR Relaxometry and Diffusometry”

Nuclear magnetic resonance (NMR) is not just a spectroscopic technique for determination of molecular structure. This sound bite will describe how NMR relaxometry and diffusometry are being used to examine chain dynamics in topologically complex macromolecules (e.g., cyclic polymers) and water dynamics in microgels. Brief mention will also be made of NMR tomography and its use to study fluid distribution and dynamics in soft materials.

Connie Roth, Emory

"Effect of Free Surface on Physical Aging of Polystyrene Films and Its Connection to Glass Transition Temperature Reductions: Evidence for a Gradient in Dynamics"

The glass transition and physical aging in nanoconfined polymer films have been heavily studied. Recently there have been an increasing number of studies pointing towards a gradient in mobility emanating from the free surface in these films. Using a new streamlined ellipsometry technique, we have measured the temperature dependence of the physical aging rate Beta for both bulk (2430 nm) and thin (29 nm) polystyrene (PS) films supported on silicon. We find that the thinner films have reduced physical aging rates at all temperatures that are inconsistent with a simple shift in the temperature dependence of Beta corresponding to the shift in Tg observed in these films. The reduced Beta values measured at all physical aging temperatures are consistent with a gradient in dynamics originating from the free surface of the film. Our data is well fit by a simple two-layer model that has been previously employed to explain the Tg reductions in PS thin films, suggesting that the enhanced dynamics present at the free surface are responsible for both effects. The surface layer thickness of this two-layer model, which increases with decreasing temperature, characterizes the depth to which the enhanced mobility at the free surface propagates into the film.

Andy Pahner, Emory

"Physical Aging Rates of Thin Polystyrene Films: Effect of In-Plane Stress during Free-Standing Quench"

Physical aging in polymers occurs after the polymer is quenched below the glass transition temperature, and due to packing frustrations, free volume exists which decreases on logarithmic time scales. This aging effect, while occurring at a microscopic length scale, has profound effects on macroscopic properties of polymeric materials. In this experiment, the physical aging rates of thin polystyrene films (500 to 1500 nm) were measured using a streamlined ellipsometry technique. It was observed that the aging rates varied when the cross-sectional area (both thickness and width) of the films was changed. We believe this change in aging rates resulted from in-plane stresses imparted on the films during the formation of the glassy state, i.e., thermal quench. These stresses are induced by a force balance between the thermally contracting film and the flexible wire frame with which the films were held during the quench. We have developed a functional form for the stress imparted to the films that agrees with the correlation observed between physical aging rates and the cross-sectional area of the film. These results are surprising because the stresses are only present during the formation of the glassy state and not during the physical aging process itself. These results also have implications for how polymer films could be processed for gas permeation applications.

Annika Kriisa, Emory

"Characterizing Phase Separation of PS/PVME Blends Using Different Fluorophores"

Controlling the early stages of phase separation in polymer blends provides the ability to obtain interconnected nanostructured domains for use in energy related applications. We are developing a fluorescence technique that will identify the phase separation temperature at earlier stages of phase separation than the classical method of light scattering. We present results comparing thermally induced phase separation in polystyrene / poly(vinylmethylether) (PS/PVME) blends using a series of different fluorescent dyes (pyrene, anthracene, naphthalene), as well as the intrinsic fluorescence of PS itself. We anticipate that a comparison of the different fluorescence signatures upon phase separation will also provide new insight into the hydrogen bonding mechanism that holds this blend together.

Hsiang-Chih Chiu, Georgia Tech

"Hindered Rolling and Friction Anisotropy in Supported Carbon Nanotubes"

Carbon nanotubes (CNTs) are well known for their exceptional thermal, mechanical and electrical properties. For many CNT applications it is very important to know the frictional properties between an individual nanotube and a substrate or an AFM tip. However, very little is known about this subject. In our group, a combined theoretical and experimental study of the frictional forces encountered with a nanosize tip sliding on top of a supported multiwall CNT along a direction parallel or transverse to the CNT axis has been achieved. Surprisingly, a higher friction coefficient was found in the transverse direction compared to that of the parallel direction. This result is well explained by a molecular dynamics simulation showing that transverse friction elicits a soft "hindered rolling" of the tube and a frictional dissipation that is absent, or partially absent for chiral CNTs, when the tip slides parallel to the CNT axis. Our findings can help in developing better strategies for large-scale CNT assembling and sorting on a surface.

Suenne Kim, Georgia Tech

"Direct Writing and Characterization of Poly(p-phenylene vinylene) Nanostructures"

We report the use of thermochemical nanolithography to convert a precursor polymer film to poly(p-phenylene vinylene) with sub-100 nm spatial resolution, in ambient conditions. The local thermochemical conversion is verified by Raman spectroscopy, fluorescence imaging, and atomic force microscopy. This convenient direct writing of conjugated polymer nanostructures could be desirable for the design and fabrication of future nanoelectronic, nanophotonic, and biosensing devices.

Debin Wang, Georgia Tech

"Nanoscale Tunable Reduction of Graphene Oxide for Graphene Electronics"

The reduced form of graphene oxide (GO) is an attractive alternative to graphene for producing large-scale flexible conductors and for creating devices that require an electronic gap. We report on a means to tune the topographical and electrical properties of reduced GO (rGO) with nanoscopic resolution by local thermal reduction of GO with a heated atomic force microscope tip. The rGO regions are up to four orders of magnitude more conductive than pristine GO. No sign of tip wear or sample tearing was observed. Variably conductive nanoribbons with dimensions down to 12 nm could be produced in oxidized epitaxial graphene films in a single step that is clean, rapid and reliable.

Keith Carroll, Georgia Tech

"Thermochemical Nanolithography: Applications and Capabilities"

Thermochemical Nanolithography (TCNL) is a recently developed lithographic technique which provides sub 15 nm resolution. By using a thermal AFM tip, we are able to locally alter surface chemistries providing us with a platform to site specifically bind various molecules including DNA and various proteins. Recent developments include the production of large patterned areas (~1mm by ~1mm), surface gradients, and complex designs. TCNL provides controlled surfaces that facilitate nanotechnology, nanoelectronics, and biotechnology.

Sound Bites II: Biological Matter

Sachin Goyal, Emory

"Continuum Modeling of DNA"

Designing and engineering DNA molecules to achieve desired biological activity has numerous applications that can lead to advances in disease prevention, diagnosis, and cure. The biological activities of DNA including gene expression are significantly influenced by its structural deformations such as looping, which in turn are tied to its chemical make-up, the base-pair sequence. For example, activity of the genes in lac-operon is governed by the sequence-dependent looping behavior of its "non-coding" DNA segment (portion of DNA that does not contain genes).

The success of designed DNA molecules for disease prevention or genetic engineering applications therefore depends on understanding not only the genetic information contained in the DNA but also the structural deformations of non-coding "junk DNA." Non-coding DNA is a significantly larger part of the genome (more than 98 % in the human genome) than the part that contains genes. The sequence-dependent structural deformation of non-coding DNA is thus a major design criterion for engineering synthetic DNA that has been mostly ignored so far. Both static and dynamic deformations of non-coding DNA play a significant role in its biological activity. Understanding and modeling these deformations and their relationship with base-pair sequences represents a significant challenge.

Among the several existing approaches to model structural deformation in DNA molecules, elastic rod models are based on a continuum approximation. Rod models are computationally efficient and are applicable to long length scales. In this approach, DNA molecules are viewed as continuous filaments. The elastic rod model predictions are, however, very sensitive to the constitutive law (material properties) of the molecule, which in turn, vary along the molecule's length according to its base-pair sequence. However, a key component of these elastic rod models is a constitutive law (material law), which follows from the bond stiffnesses and other atomistic-level interactions. A simplistic view of this constitutive law is that it represents the "springiness" of the DNA molecule and its relationship to its atomistic structure. The general form of constitutive law remains largely unknown, and the capability to estimate the correct form that governs DNA structure and dynamics is severely limited by the absence of a systematic approach to best leverage the limited data available. In this presentation, I will motivate our ongoing research that can use a rod model in combination with high-fidelity molecular dynamics simulation data to estimate the constitutive law.

Qing Shao, Emory

"Effects of Spermine on DNA Supercoiling and Duplex Stability"

Polyamines are low molecular weight, aliphatic, polycationic compounds found in all cells. Spermine, one of the most important polyamines, can interact electrostatically with DNA and RNA, because of the (+4) positive charge. Due to this interaction, spermine plays very important roles in the regulation of gene expression and translation as well as mitosis. Previously, most studies of the interaction between DNA and spermine focused on the condensation of DNA due to neutralization of negative charges by spermine, or the interaction of spermine with short DNA segments, and gave little insight into how spermine alters the structural mechanics of DNA. We use single-molecule manipulation experiments with magnetic tweezers to investigate the stretching behavior of single DNA molecules under torsion with different spermine concentrations. Our results reveal that spermine not only reduces the size of DNA supercoils, but also stabilizes the double helix perhaps by bridging the two strands of a DNA duplex. Intuitively it is clear how enhanced duplex stability might oppose gene expression. Furthermore, since spermine concentration rises dramatically during mitosis, our results prompt the hypothesis that tightly coiled and duplexed double-stranded DNA facilitates mitosis.

Tung Le, Georgia Tech

"Reentrant DNA Condensation by Multivalent Counterions"

DNA-DNA interaction mediated by counterions is studied using computer simulation. In case DNA configurational entropy is restricted, divalent counterions can cause DNA reentrant condensation. The DNA-DNA interaction is strongly repulsive at small or large counterion concentration, and is slightly attractive for a concentration in between. The charge inversion phenomenon for DNA is reconfirmed and the dependence of energy of packaging DNA into bundle on the radius of counterions agrees qualitatively with theoretical prediction.

Vikram Prasad, Georgia Tech

"Rheology of Algae Suspensions"

We grow algae suspensions in a photobioreactor, which causes their number density to grow as a function of time. Simultaneously, the viscous properties of the suspensions under steady shear are monitored. We find that the suspensions show shear-thinning behavior, primarily caused by polysaccharides released by the algae into solution. However, even after the polysaccharides are eliminated from solution by centrifugation, the residual algae still retain shear-thinning behavior. This is postulated to be caused by a dense coating of polysaccharides still adhering to the cell membrane of the algae.

Kyung Duk Koh, Georgia Tech

"Detection and Quantification of Ribonucleotides Embedded into DNA"

There is an increasing number of evidences suggesting that ribonucleotides may represent one of the most common non-standard nucleotides found in genomic DNA. DNA polymerases, including yeast replicative polymerases, have been shown in vitro to frequently incorporate ribonucleotides while DNA primases can potentially embed one or several ribonucleotides into DNA by incorporating deoxynucleotides in the primer sequence. In addition, deoxynucleotides can be converted to ribonucleotides by oxidative damage. Currently, no measure was done to determine the abundance of ribonucleotides in nuclear DNA. Our hypothesis is that ribonucleotides that are embedded into DNA, even if present only transiently and in small stretches in DNA, can change the mechanical properties of DNA altering DNA replication and transcription, affecting the genetic integrity of DNA, and/or acting as signaling for epigenetic modifications. Thus, revealing how abundant ribonucleotides normally are in DNA and what factors affect their content in DNA can shed light on the potential of ribonucleotides to contribute to genomic modification and variation in cells. Two unique experimental systems are being developed and standardized to reveal and quantify the presence of ribonucleotides embedded into DNA. One method involves labeling ribonucleotide sites with a fluorophore and measuring the intensity of fluorescence by a fluorometer. The other method involves extracting ribonucleotides from the DNA duplex by sequential enzymatic and chemical reactions and detecting them by mass spectrometry.

James Hardin, Georgia Tech

"Controlled Release of DNA from Gelatin Blocks and Microspheres"

Olignucleotides are important both as therapeutic agents and as colloidal assembly tools; however, the encapsulation of DNA in a biocompatible matrix and controlled release of DNA from this matrix present major challenges. Gelatin possesses key advantages as a biocompatible semipermeable matrix that can undergo a thermally reversible phase transition in the relevant temperature range for processing and medical applications. Gelatin-based biomaterials are commonly prepared by chemically crosslinking the gelatin and thus rely on subsequent enzymatic degradation of the gelatin to release encapsulated agents. In this study, however, we used uncrosslinked gelatin to preserve its temperature dependent behavior. Gelatin microspheres were first synthesized using a water in oil emulsion and then infiltrated with fluorescently-labeled DNA strands. Lastly, a thin polymer capsule was added to the microspheres using LbL deposition of poly(acrylic acid) and poly(allylamine hydrochloride). 150µL gelatin blocks containing fluorescently-labeled DNA were used as a model system. The release of DNA over time from these gelatin blocks was quantified through supernatant analysis using DNA functionalized polystyrene microspheres. At room temperature, little if any DNA was released from the solid-like gelatin blocks with polyelectrolyte coatings. A marked increase in DNA release, however, occurred from liquid-like gelatin blocks at 37oC. Very little temperature dependence was observed in the release from uncrosslinked blocks below a gelatin concentration of 40%. A similar trend was seen in the release of DNA from gelatin microspheres.

Sven Behrens, Georgia Tech

"Prediction and Accelerated Test of Protein Aggregation"

The efficacy of therapeutic proteins (and their FDA approval) depends on their stability against aggregation in solution. Long term stability in particular is tedious to monitor experimentally and cannot be predicted reliably. Here, we propose heuristic arguments for a strong connection with the concentration dependence of protein diffusivity, which can be measured in a matter of minutes. For two globular model proteins we show that the experimentally observed kinetics of salt-induced aggregation indeed correlates nicely with diffusivity data obtained in stable solutions of similar ionic composition but lower ionic strength. Our results suggest a fast and convenient way of predicting medium-specific aggregation trends in proteins of pharmaceutical interest.

Ryan Maladen, Georgia Tech

"Principles for Undulatory Swimming in Granular Media"

Swimming within sand is common to many desert dwelling organisms that escape into the media to avoid predators and hunt prey. Being able to utilize kinematics that maximizes their forward speed would be seemingly advantageous. We integrate biological experiments, numerical simulation, and physical modeling to discover general principles for undulatory swimming in sand. Recent work using high speed x-ray imaging demonstrated that the sandfish lizard (Scincus scincus) swims within granular media without limb use by propagating a single period traveling sinusoidal wave posteriorly down its body. We developed a numerical model that couples a model of the sandfish to a validated Molecular Dynamics granular media simulation to investigate the effect of undulatory kinematics on performance. The simulation predicted that the spatial form (ratio of amplitude to wavelength) of the sandfish allowed it to maximize its speed. To test the generality of this prediction for undulatory swimming in a physical test environment while avoiding the physiological constraints imposed by the animal, we designed and tested a sand swimming robot. Consistent with our numerical sandfish model, the robot reveals that the maximum forward speed during subsurface undulatory locomotion corresponds to the same kinematics as the sandfish.

Jan Krajniak, Georgia Tech

"Developmental Studies of Higher Organisms"

Tracking development of individual animals can provide insights into dynamics of processes such as synaptogenesis, synaptic re-arrangement, and axonal growth cone development. However, such longitudinal studies are experimentally complicated and sometimes impossible to perform on the basis of individual worms; this is largely due to negative effects of anaesthetics on physiology and development and the difficulty of keeping track of individual worms. We developed a platform to i) repeatedly immobilize animals at physiological temperature and conditions, ii) perform high-magnification imaging while keeping track of individual specimen, and iii) culture animals between imaging cycles for proper development for days. The platform is based on the thermo-reversible sol-gel transition of a polymer solution (within 1 degree Celcius), which is used for the reversible immobilization of animals. A microfluidic system is used in conjunction for animal trapping, nutrient delivery, and fluid and precise temperature control. Worm embryos are trapped in individual chambers via connected embryo traps. Gentle flow of M9 with OP50 bacteria and cholesterol is delivered into each chamber, allowing animals to

feed and develop while trapping them inside the chamber. Precise temperature modulation by integrated microelectrodes controls the sol-gel transition for immobilization; the devices are ease to set up, re-usable, and economical. During immobilization, the gel exerts uniform pressure along the animal body, and thus leads to negligible physical deformation. Image quality (e.g. amount of diffraction, photo-bleaching) when using the gel is comparable to that of standard methods with anaesthetics. We have verified the gel's biocompatibility with C. elegans; repeated and long-term exposure and immobilization show no effect on measured physiological traits such as pharyngeal pumping rate, number of progeny, and time to reach egg-laying.
We tested the functionality of our system by monitoring the re-arrangement of synaptic connections of the six GABAergic motor neurons at the end of the L1 larval stage (Hallam and Jin, Nature, 1998). To our knowledge, our platform is the only system to date that facilitates longitudinal studies in the early stages of development on an individual-animal basis. It is also the first to enable live imaging of short-term (order of seconds) to long-term (hours and days) developmental events at arbitrary intervals on a single device.

Jeffrey Stirman, Georgia Tech

"Spatial and Temporal Optical Activation of Neurons in Freely Behaving Worms"
Optogenetic tools, such as the light-gated cation channel channelrhodopsin-2 (ChR2), are one of the most intriguing recent advances in the field of neuroscience. Selective activation of individual nodes of a neuronal network allows one to disect neural circuits with greater precision and elucidate roles of neurons and specific network behavior. In addition, performing these experiments on freely behaving worms allow correlations of circuit activity to behavior. Optical stimulation to date have only been demonstrated for whole animal illumination or illumination of specific regions of immobilized animals. Therefore, new tools for spatial and temporal control of optical activation while tracking behaivor in freely moving animals are needed. We created an integrated system capable of tracking freely moving animals and controlling the spatial (at the cellular level) and temporal (~20 ms) illumination of ChR2. The system includes a motorized XY-translational stage, an inexpensive commercial DLP projector, and custom software. It is capable of automatically optically targeting specified locations along the body of freely crawling worms and controlling the illumination duration and intensity – allowing illumination of single neurons or subsets of neurons in an unrestrained worm. In a preliminary study we demonstrate precise spatial and temporal control by targeting specific body segments in a strain carrying ChR2 in the cholinergic motor neurons. Photo-stimulating the worm head allows us to control the crawling direction, and thus dictate specific locomotive paths. Illuminating the mid-body interupts normal wave propagation, resulting in kinked body postures. To further demonstrate the capability of this system, we have used a strain expressing ChR2 in the six gentle touch receptor neurons. We use the illumination system towards a detailed analysis of the contributions and integration of signals within the gentle touch circuit. Unlike manual touch, we can examine responses illicited by sequential or simultaneous neuronal stimuli at precisely controlled intervals, intensities and durations, which would allow studies of sensory signal integration in behavior not previously possible.
We would like to thank Yoshinori Tanizawa and Bill Schafer for their generous gift of the pmec-4::ChR2 strain.

Hyewon Lee, Georgia Tech

"Understanding Environment-responsive Transcriptional Regulation in C. elegans Using Microfluidic System"
Changes of gene expression contribute the heterogeneity in physiology. To understand various physiological outcomes, we need to analyze the detailed mechanism of transcriptional regulations which affect gene expressions. Caenorhabditis elegans (C. elegans) has been broadly used for gene-expression analysis because of its transparent tissue, completely sequenced genome, mapped neuron wiring, and the ease of applying genetics. To reveal the regulatory mechanism from environmental perception to downstream of sensing pathway including insulin-like pathway that modulates aging, we focus on tryptophan hydroxylase (tph) gene expression. TPH is a key enzyme involved in the synthesis of the neurotransmitter serotonin, which is located in neurons sensing various environmental cues such as temperature and food. To acquire meaningful statistics in study, thousands of worms must be examined. Microfluidics allows for high-throughput and high-resolution imaging, and quantitative imaging is necessary for quantifying subtle gene-expression level change. In parallel, quantitative image-analysis for phenotyping will be developed using a MATLAB program. From these studies, in the long run, we may

predict the physiological consequence of individual bases by defining the relationships between genetic pathways and environmental factors.

Sharon Hamilton, Georgia Tech

"Progress Towards Tunable Hydrogel Co-Culture Systems"

Recently there has been an increased interest in the exploration and understanding of the effects of paracrine signaling between groups of cells, for example within the joint organ. Most methods currently used for studying cell co-cultures in 3D lack the ability to effectively separate the two cell populations after the determined culture period. We are developing a patternable and tunable 3D hydrogel co-culture system that will allow us to culture different cell types and subsequently separate the cells based on population. This will allow us to elucidate the effects of co-culture on each individual population of cells to better understand cell-cell interactions, and how the interaction affects cell differentiation and proliferation. The technology developed broadly enables co-culture and individual cell population analysis and represents an important attempt to use a controlled, separable, 3D environment to facilitate research on paracrine signaling.

Taymour Hammoudi, Georgia Tech

"Hydrogel Biomaterials for Stem Cell Co-Culture and Study of Cellular Crosstalk"

Local delivery of marrow stromal (stem) cells (MSCs) offers a potentially viable alternative to auto-/allograft transplants for repair of injured tendons/ligaments. Knowledge regarding MSC interactions with native cells and resulting effects on cell proliferation, matrix production, and tissue repair would enhance development of these strategies. Here, we detail methods for 1) controlled cell patterning in three dimensions (3D) using a photolithographically prepared co-culture system based on oligo(polyethylene glycol)-fumarate (OPF) hydrogels, and 2) facile separation of modules of cells post-culture for further analyses using a photocrosslinkable, enzyme-digestible "glue" based on chondroitin sulfate (CS). Bulk hydrogels of CSMA may be synthesized with multiple degrees of methacrylation that affect gel swelling ratio (20-40 fold) and degradation rate (80-200 min), making it a viable photocrosslinkable "glue" to separate photopatterned OPF:PEG-DA hydrogel blocks. Gel degradation time correlates with swelling ratio, suggesting the network mesh size affects penetration and/or activity of chondroitinase ABC. We subsequently laminated OPF:PEG-DA hydrogels in complex patterns and evaluated viability of cells in long term culture. LIVE/DEAD staining demonstrated that remaining patterned cells are viable after 14d in culture. DNA content, indicative of cell number, shows little decrease over time, which supports the use of this system for long-term culture. We are able to pattern a complex checkerboard of cells with controlled location of each cell population that is consistent throughout the 1.5mm-thick blocks. Patterning CSMA gels between blocks enables separation after long term culture via enzymatic degradation, demonstrating our ability to separate cell populations after co-culture for further gene/protein expression analysis. In these studies, we have developed a spatially controlled 3D environment for culturing multiple cell types over weeks, followed by separation of blocks to analyze each cell type separately. Such a system has tremendous potential to enable better understanding of paracrine effects on a range of stem cell functions and will inform the design of stem-cell based therapies for orthopaedic and other injuries.

Harold Kim, Georgia Tech

"How DNA Packaging Influences Genetic Code Processing"

Transcription factors are proteins that bind to specific DNA sequences and initiate transcription. However, binding of transcription factors can be hindered because DNA in eukaryotes (for example, yeast, humans, etc) is highly compacted into nucleosomes; very much like winding a string around a bead. We want to study how transcription factors bind DNA in the presence of nucleosomes, and how the competition between transcription factors and nucleosomes influences transcription in a quantitative manner. I will present how we will tackle these questions using fluorescence microscopy.

Gabriel Mitchell, Georgia Tech

"Quantifying Enzymatic Lysis by Combining Theoretical and Experimental States of Information"

We present a new standard for the analysis of turbidity assays of bacteriolytic enzymes. Turbidity assays have long been used to explore the action of enzymes on bacterial cell walls. The central challenge in the analysis of these assays is to infer the microscopic details of lysis from the macroscopic turbidity data. The current method for analyzing these assays is based on measuring the time it takes for a known titer of enzyme to decrease the turbidity by half. While quantitative, this approach offers no insight into the microscopic details of lysis. Our analysis focuses on a model of enzymatic lysis that integrates the chemistry responsible for cleavage of bonds with the physical mechanisms leading to cell wall failure and lysis. By combining reaction time series with a cell's susceptibility to lysis as a function of the number of bonds cleaved on the cell wall we obtain a fraction of lysed cells in the population at any time, from which we construct a model turbidity time series. We are then left with an inverse problem in which we estimate reaction rate constants and the putative lysis susceptibility function given the turbidity data. As support for our method we demonstrate accurate reconstruction of synthetic turbidity time series data from both deterministic and stochastic reaction kinetics. Finally, we validate our method's applicability to experimental turbidity data of bacterial lysis by characterizing the reaction kinetics of egg-white lysozyme, a well-characterized enzyme, and the lysis susceptibility of micrococci.

Sound Bites III: Fluid and Granular Matter

Venkata Gundabala, Georgia Tech

"Current-voltage Characteristic in Electro-Coflow"

Here we use a novel glass-based microfluidic device in a novel way to quantify the behavior of electric current as a function of operating parameters and find that unlike in classical electrospray, there is a strong voltage dependence and a weak flow rate dependence of the electric current.

Ekapop Pairam, Georgia Tech

"Growth and Collapse, an Evolution of Fat Toroidal Droplets"

Thin toroidal droplets evolve into spherical droplet via Rayleigh-Plateau Instability. The evolution of fat toroidal droplets take on different mechanism and is not well understood. This presentation gives a closer look at an instability of fat toroidal droplets.

Ivan Caceres, Georgia Tech

"Rapid Phenotyping and Visual Screens Enabled by Microfluidics"

Since its introduction in 1974, the model organism Caenorhabditis elegans has played a crucial role towards discoveries in the fields of neural development and genetics. With genes homologous to many vertebrates, the animal provides an opportunity to study complex neural and genetic pathways in a comparatively simple environment. However, studying these mechanisms using current technologies such as quantitative microscopy is difficult. This is because standard methods (phenotypic screens) are performed manually and introduce bias into experimental analysis. In addition, animals with subtle phenotypes make classification more difficult for experimenters, requiring more time for analysis, and decreasing the throughput and efficacy of phenotypic screens. These issues together play roles in limiting the discovery of novel genes involved in neural development and neurodegeneration and bottleneck the advancement of C. elegans research. My thesis work aims to develop a method for high-throughput and automated phenotypic screens of C. elegans in order to identify neural-development and neurodegeneration mutants. To achieve this goal I will improve upon existing methods for imaging, immobilizing, and sorting worms in microfluidic chips, simplifying devices for operation by scientists, not engineers. The proposed device will be constructed from polydimethylsiloxane (PDMS) using the well-established soft lithography process and will immobilize nematodes by constricting their movement within an imaging chamber without the use of anesthetics. This will be accomplished by limiting the animal's range of motion in conjunction with physical compression within the device. In parallel, I will develop image analysis software to quantify characteristics of specific neuronal features to phenotype animals. Lastly, to validate the proposed technology I will screen with the goal of discovering at least three novel genes that effect neuronal development (specifically neuronal polarity and axon guidance) and neurodegeneration. The screen will be performed using a C. elegans strain which expresses green fluorescent protein (GFP) in a tail sensory neuron, PQR. I plan to identify mutants by searching for irregularities in PQR neuron morphology.

Alison Hirsch, Georgia Tech

"Particle Behavior in Microfluidic Mixers: Experiments and Modeling"

Many processes, especially in bioengineering, are now carried out in microfluidic systems. At the micro-scale, mixing of solutes is predominantly a diffusion process due to the laminar nature of fluid. Many different mixing strategies have been employed to effectively decrease the characteristic length for diffusion. For example, the Staggered Herringbone uses carefully designed grooves on the surface of the channel to laterally fold and stretch the fluid, and an even mixing of solutes/solvents can be achieved relatively quickly. However, particle (or cell) mixing behavior in fluid is still not well understood. To assess the critical factors behind neutrally buoyant particle mixing or focusing, we implemented a series of experiments with varying flow conditions, fluid and particle properties, and geometries. Using a novel experimental method we were able to acquire three-dimensional particle distribution information without using expensive confocal microscopy. As expected, based on our previous observation, solute and particles mix differently in the same device under the same flow conditions. We ran a series of experiments to elucidate the effect of several variables on the particle distribution: flow rate (Re), particle size, and groove geometry. These experiments revealed the particle size and groove geometry to be most significant within the Reynolds number range examined (~0.2-2). To explain these results, we hypothesize that the finite particle have a defined set of accessible streamlines; streamlines that come within a distance equal to the particle's radius from the wall cannot contain particles. Computational fluid dynamics simulations performed to confirm this hypothesis. By studying particle mixing of various particles under different flow conditions, we hope to provide a more comprehensive view of the particle-fluid behavior in laminar flow. With this knowledge, efficient unit operations in multiphase systems, including mixing, concentration and separation, can be designed, particularly in microfluidic technologies for many biological and medical applications that handle cells and beads.

Edward Park, Georgia Tech

"Microfluidics - Complex Microenvironments for Cell-Based Assays"

The principal aim of this research is to develop microfluidic technologies to improve the capabilites and throughput of living cell-based assays. Living cell-based assays are in vitro testing tools that are essential to the life sciences and the pharmaceutical industry; however, today's assays are unable to replicate the complex microenvironment that surrounds cells in vivo. As a result, cellular response in assays is frequently a poor indicator of how cells respond in their native environment. A central challenge in living cell-based assays is to make them capable of producing complex microenvironments that emulate physiologically relevant conditions. We are developing two novel microfluidic technologies to address challenges with standard and microfluidics-based assays. First, we present a cell culture array with unique versatility and parallelization for experimental trials requiring perfusion cultures. Specifically, we realize a rectangular chamber array in a PDMS device with three attributes: (i) continuous perfusion; (ii) flow paths that forbid cross-chamber contamination; and (iii) chamber shielding from direct perfusion to minimize shear-induced cell behaviour. These attributes are made possible by a bridge-and-underpass architecture, where flow streams travel vertically to pass over (or under) channels and on-chip valves. The array is also designed for considerable versatility, providing subarray, row, column, or single chamber addressing. It allows for incubation with adsorbed molecules, perfusion of differing media, seeding or extraction of cells, and assay staining. We use the device to characterize different phenotypes of alveolar epithelial type II (ATII) cells, particularly the extent of epithelial-to-mesenchymal transition (EMT), a highly suspected pathway in tissue regeneration and fibrosis. Cells are cultured on combinations of matrix proteins (fibronectin or laminin by row) and soluble signals (transforming growth factor-beta1 +/- by column). Assay and morphological data are used to tease-out effects of cues driving each phenotype, confirming this as an effective and versatile combinatorial screening platform.

Second, we present a microfluidic device that generates non-shearing and switchable concentration gradients using a simple technique in which fluid flows are discretized within an array of cell chambers. Discretized flows are made possible by a unique architecture comprised of 3-dimensional flow paths and on-chip valves, which guide and stop flows within the supporting channel network. This new approach surmounts existing technical trade-offs, providing experimentalists with non-shearing and directionally-switchable gradients that span the entire normalized concentration gamut (0 to 1) within an highly scalable chamber array architecture. We validate the technology by measuring the response of cells to growth factor gradients. They are tracked by calculating centroid trajectories from traces of cell edges, yielding step-velocities and numerous morphological readouts (e.g. aspect ratio, angular orientation). These data are compared by diverse graphical and statistical means. We aim for this technology to form the basis of high-throughput, high-content cell migration assays with broad applicability to many cells types and studies.

Fengshou Zhang, Georgia Tech

"Fluid Injection into Granular Media in Hele-Shaw Cells"

Fluid injection into granular media is relevant to many civil, environmental and petroleum engineering applications. Due to the highly nonlinear constitutive behavior of the granular media and the strong coupling between fluid flow and mechanical deformation, the process of fluid injection in weak porous media is still poorly understood. To better understand the fundamental failure and flow mechanisms involved in the fluid injection process in granular media, a series of experiments were carried out in a

Hele-Shaw cell-like setting. The Hele-Shaw cell consists of two PMMA square plates with a narrow gap with fine sands filled in between the plates. Aqueous glycerin solutions were injected from the center of the bottom plate. Preliminary experimental results show that flow patterns emerge from competition among various forms of energy dissipation, i.e., viscous dissipation through flow in porous media, dissipation in mechanical deformation, and viscous dissipation through flow in thin channels. As a result, four distinct failure/flow regimes can be identified.

Yang Ding, Georgia Tech

"Drag Induced Lift in Granular Media"

Laboratory experiments and numerical simulation reveal that a submerged intruder dragged horizontally at constant velocity within a granular medium experiences a shape dependent vertical force Fz. We measured Fz for shapes with difference curvature and symmetry. Here we show that the buoyant force experienced by an intruder is determined through three effects: the vertical component drag induced lift from grain collisions, asymmetric flow due to gravity, and frictional lifting at the leading surface of the object.

Nick Gravish, Georgia Tech

"Flow and Fracture in Granular Media"

We demonstrate in a three-dimensional laboratory plate drag experiment that a granular medium (250~μm glass beads) exhibits a bifurcation from fluid-like to jammed flow as the volume fraction (ϕ) is increased above a critical value $\phi_c=0.603 \pm 0.0025$. We measure the force F_d on a flat plate (3.8~cm width, 10.0~cm depth) dragged at constant velocity v through the surface of a granular medium for $0.57<\phi<0.63$. For $\phi<\phi_c$, F_d is independent of time and particle image velocimetry indicates that the flow of the granular media is uniform around the plate. For $\phi>\phi_c$, F_d displays large periodic fluctuations which correspond to the formation of shear bands. Surface profile measurement of the post-drag net displaced volume ΔV of the granular material reveals that the medium compacts ($\Delta V<0$) in response to drag for $\phi<\phi_c$ and expands ($\Delta V>0$) for $\phi>\phi_c$. Thus the transition to jammed flow at ϕ_c is marked by the onset of dilation in granular media.

Kenneth Desmond, Emory

"Force Chains & Granular Temperature of 2D Frictionless Emulsion Droplets"

We use a quasi-two-dimensional emulsion as a new experimental system to measure various jamming transition properties. Our system consist of confining oil-in-water emulsion droplets between two parallel plates, so that the droplets are squeezed into quasi-two dimensional disks, analogous to granular photoelastic disks. By varying the droplet area fraction, we investigate the force network of this system as we cross through the jamming transition. At a critical area fraction, the composition of the system is no longer characterized primarily by circular disks, but by disks deformed to varying degrees. Quantifying the deformation provides information about the forces acting upon each droplet, and ultimately the force network.

Dandan Chen, Emory

"Observing Rearrangements in a 2D Emulsion Flowing through a Hopper"

Jamming in granular flow through a hopper has been well studied, and structures such as arches have been found in simulations both with and without friction, and in experiments with friction. To study if jamming can happen in other frictionless systems, we pump dense emulsions (oil in water) through a glass hopper. The oil droplets experience a viscous friction but do not have static friction acting between touching droplets, in contrast to granular particles. For easy imaging, we squeeze the droplets into quasi two-dimensional disks by injecting the emulsion into a thin chamber made from two parallel glass plates. Movies of the flow are taken from the top by a microscope. Due to the narrowing confinement in the hopper, droplets are forced to rearrange, and we observe topological changes such as T1 events. At the same time, the interdroplet forces are measured from the deformation of the droplets. By varying the hopper gap width and angle, we study how the constriction affects the particles' motions, and how this relates to the interdroplet forces.

Laura Golick, Emory

"Deformation of Quasi-2D Oil-in-Water Emulsions"

We create a quasi-2D nearly frictionless granular system, analogous to 2D granular systems of photoelastic disks but without static friction. To do this, we confine an oil-in-water emulsion between two glass plates such that the gap between the plates is smaller than the undeformed oil droplet diameter. For a range of droplet area fractions and plate separations, we observe the deformations the oil droplets experience due to contact with each other. The deformation of the droplet is correlated to the force its neighbors exert on it. As area fraction increases, the deformation of the droplets increases. By looking at the pattern of deformations throughout the system we visualize the location of force networks due to droplet-droplet interactions.

Xia Hong, Emory

"Jamming of Oil in Water Emulsion Flow in a 2D Hopper"

Granular systems consist of particles which interact among themselves only by interparticle contacts. Many natural phenomena could be related to granular flow, which is, however, lack of fundamental explaination in its properties.For example, in the jamming process of granular flow in a 2D hopper,studies showed that jamming is due to arch formation at the hopper beginning and friction could help increase the jamming prabability.Instead of using monodisperse 2D disks, in our study, we tried 2D oil in water emulsion flowing in a narrow 2D hopper which are liquid droplets without static friction and only have viscous friction. We have performed experiments on the jamming phenommenon of monodisperse oil in water emulsion in 2D hopper in the gravity field, and measured the relation between the jamming probability and the ratio of the opening width and the size of droplets.We found that jamming is also due to arch formation but not necessarily convex, and proved that static friction largely contributes to the jamming phenomenon. In addition, we also found some interesting phenomenon which might be related to breaking a crystal.

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