

PROGRAM

May 25th 2011
5th South-East
Workshop on
Soft Materials

Elisa Riedo and Daniel Goldman

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Program

5th South-East Workshop on Soft Materials and Interfaces

Georgia Institute of Technology

May 25th, 2011

Nano Building on Georgia Institute of Technology Campus

(Marcus Nanotechnology)

Registration, Breakfast, and Breaks:

1st Floor Center Gallery

Seminars: Conference Room 1116



8:30 AM - 9:00 AM

Breakfast and Registration, 1st Floor Center Gallery



9:00 AM - 9:10 AM

Welcome from Elisa Riedo and Daniel Goldman, Conference Room 1116

Morning Invited Speakers (Chair: Eric Weeks)

9:10 AM - 9:55 AM

M. Cristina Marchetti, Department of Physics, Syracuse University

Collective Motion: from Minimal Models to Hydrodynamics

10:00 AM - 10:45 AM

Juana Mendenhall, Department of Chemistry, Morehouse College

Using Innovative Tunable Thermo-responsive Poly(N-vinylcaprolactam) Soft Materials to Solve Problems in Bioengineering



10:45 AM - 11:00 AM

Coffee, 1st Floor Center Gallery



11:00 AM - 12:00 PM

Sound Bites I: Soft Condensed Matter and Polymers

(Chair: Alberto Fernandez-Nieves)

Kenneth Desmond, Emory

Designing a Shear Cell for Quasi-2D Emulsions

Gary Hunter, Emory

Effect of Boundary Mobility on the Dynamics of Confined Colloidal Suspensions

Juan Jose Lietor-Santos, Georgia Tech

Bulk and Shear Moduli of Packed Microgel Suspensions

Hongzhi Wang, Georgia Tech

Effect of Electrostatic Interactions on Pickering Emulsions

John Hyatt, Georgia Tech

Microgel Suspensions Studied Using Cross-Correlation Light Scattering

Hsiang-Chih Chiu, Georgia Tech

The Impact of Defects on Frictional Properties of Carbon Nanotubes

Hassan Masoud, Georgia Tech

Fast release of Nanoparticles from Microgel Capsules

Justin Pye, Emory

Evidence for Two Simultaneous Mechanisms Causing Tg Reductions in High Molecular-Weight Free-Standing Films Observed as Dual Glass Transitions in a Single Film

Laura Gray, Emory

Effect of Quench Conditions on the Subsequent Physical Aging Rate of Polymer Glasses

Matthew Kincer, Georgia Tech

Polymeric Templating and Alignment of Fullerenes

Sven Behrens, Georgia Tech

New Applications for Polymers with Switchable Solubility

Khalid Salaita, Emory

Mechanics of Intermembrane Junctions

Stephanie Lin, Georgia Tech

Crystallization Kinetics of Cellulose-Based Nanocomposites

Rudra Choudhury, Georgia Tech

Polymer Chain Dynamics Determined by Solid-State NMR and Correlated with Enhanced Barrier Properties

Xuxia Yao, Georgia Tech

Prediction of Flow Behavior of Chromonic Liquid Crystals



12:00 PM - 1:20 PM

Lunch and Discussion, 1st Floor Center Gallery



Afternoon Invited Speakers (Chair: Daniel Goldman)

1:20 PM - 2:05 PM

Susanne Ullrich, Physics and Astronomy, University of Georgia

The Photoprotective Properties of Adenine: Wavelength Dependence of Electronic Relaxation in Isolated Adenine studied by UV Fs Time-Resolved Photoelectron Spectroscopy

2:05 PM - 2:50 PM

Elisa Riedo, School of Physics, Georgia Tech

ThermoChemical NanoLithography TCNL: Nanofabricating on Soft and Flexible Materials



2:50 PM - 3:05 PM

Coffee and Cookies, 1st Floor Center Gallery



3:05 PM - 3:50 PM

**Sound Bites II: Biological Matter and Flexible Devices
(Chair: Harold Kim)**

Sarah Steinmetz, Georgia Tech

Muscle Activation Strategy in Swimming Sandfish Influenced by Granular Drag Force

Andrew Masse, Georgia Tech

Vertical Position Control in a Bioinspired Sand-Swimming Robot

Tung Le, Georgia Tech

Dynamics of sequence-dependent DNA bending

Daniel Kovari, Georgia Tech

A Novel Force Assay to Quantify Contractile Forces during Phagocytosis

Louis McLane, Georgia Tech

Mechanical Measurements of the Pericellular Coat

Gabriel Mitchell, Georgia Tech

Biophysical Models of Enzymatic Lysis

Jan Scrimgeour, Georgia Tech

Microfluidic Dialysis Cell for Characterization of Macromolecule Interactions

Keith Carroll, Georgia Tech

ThermoChemical Nanolithography: Applications for Studying Heat Transfer

Suenne Kim, Georgia Tech

Direct Fabrication of Arbitrary-Shaped Ferroelectric Nanostructures on Plastic, Glass, and Silicon Substrates

Mauricio Bedoya, Georgia Tech

Solution-Gating of Epitaxial Graphene for Chemical Sensing



3:50 PM - 4:30 PM

**Sound Bites III: Fluids and Grains
(Chair: Sven Behrens)**

Annie Lesiak, Georgia Tech

Phase Diagram of Water from computer Simulations

Neus Vilanova, Georgia Tech

Droplet Size Control in Electro Co-Flow

Venkata Gundabala, Georgia Tech

Whipping in Electro-Coflow

Ekapop Pairam, Georgia Tech

Stabilization of Toroidal and Higher Genus Droplets Using Viscoelastic Media

Kazem Edmond, Emory

Decoupling of Rotational and Translational Diffusion in Supercooled Colloidal Fluids

Deborah Ortiz, Georgia Tech

Water Nano-Hydrodynamics: The Interplay between Interfacial Viscosity, Slip and Surface Chemistry

Nick Gravish, Georgia Tech

Relaxation of Entangled Granular Piles

Chen Li, Georgia Tech

Resistive Force Theory Explains Force Generation During Rotational Intrusion into Granular Media

Yang Ding, Georgia Tech

Kinematic Theory for a 3-Link Sand Swimmer

Minsu Cha, Georgia Tech

Dissolution Implication in Granular Media



4:30 PM - 4:45 PM

Coffee and Cookies, 1st Floor Center Gallery

Afternoon Invited Speakers

4:45 PM - 5:30 PM

Paul Goldbart, School of Physics, Georgia Tech

Heterogeneous Solids and the Micro/Macro Connection: Structure and Elasticity in Architecturally Complex Media as Emergent Collective Phenomena

Title and Abstracts:

Invited Speakers:

M. Cristina Marchetti, Physics Department, Syracuse University

“Collective Motion: From Minimal Models to Hydrodynamics”

A variety of living and nonliving systems, from bacterial suspensions to vibrated granular layers and bird flocks, exhibit fascinating collective behavior, including nonequilibrium phase transitions from disordered to ordered, coherently moving phases and pattern formation on various scales. In this talk I will describe our work on using nonequilibrium statistical physics to derive a continuum description of active suspensions from specific models of single particle dynamics, highlighting the role of physical interactions in controlling the large-scale behavior.

Juana Mendenhall, Department of Chemistry, Morehouse College

“Using Innovative Tunable Thermo-responsive Poly(N-vinylcaprolactam) Soft Materials to Solve Problems in Bioengineering”

Thermo-responsive materials have become of interest due to their response towards external stimuli such as temperature. In our research group, we have begun exploring one thermo-responsive material, poly(N-vinylcaprolactam) [PVCL] to address problems in such as Osteoarthritis (OA) and bioethanol production. PVCL undergoes a lower critical solution temperature (LCST) which displays a tunable phase transition dependent upon the solvent used for polymerization and molecular weight. Our efforts consist of the synthesis, preparation, and characterization of PVCL homopolymers, PVCL-grafted copolymers, and electrospun PVCL fibers. Using free-radical polymerization, we have prepared end-functionalized PVCL homopolymers and grafted copolymers that form hydrogels and display a range of LCST. These temperature-responsive hydrogels will be employed as injectable gels used to treat OA via a therapeutic entity in the polymer backbone. Additionally, PVCL nanofibers have also been prepared with various size distributions and morphologies. These PVCL nanofibers when combined with cellulose show promise as novel affinity membranes towards quantifying enzyme activity and simple sugars at various temperatures. This information will be essential when producing bioethanol using microorganisms such as termites.

Susanne Ullrich, Physics and Astronomy, University of Georgia

“The Photoprotective Properties of Adenine: Wavelength Dependence of Electronic Relaxation in Isolated Adenine studied by UV Fs Time-Resolved Photoelectron Spectroscopy”

The UV photostability of biomolecules is determined by their excited state electronic relaxation mechanisms. To be effective, these mechanisms must operate on ultrafast timescales in order to dominate over competing photochemical processes that potentially lead to destruction of the biomolecule. Femtosecond time-resolved photoelectron spectroscopy (TRPES) provides unique capabilities for studying photoinduced processes in small polyatomic molecules. Changes in the PES, observed as the delay between the pump and probe pulses is scanned, can be associated with electronic configurational changes during the relaxation process. Analysis based on ionization correlations allows us to extract the electronic character of the excited states in addition to their lifetimes. Details of the experimental setup and technique will be presented in this talk as well as our results on the deactivation pathways in the DNA base adenine following excitation by wavelengths between 200-266 nm.

Elisa Riedo, School of Physics, Georgia Tech

“ThermoChemical NanoLithography TCNL: Nanofabricating on Soft and Flexible Materials”

This presentation will overview the applications of ThermoChemical NanoLithography to different soft and flexible materials. In particular it will be shown TCNL applied to polymers for proteins and DNA arrays, TCNL applied to conjugated polymers for organic electronics applications, TCNL applied to ferroelectric oxides for energy harvesting applications, and finally TCNL applied to graphene oxide.

Paul Goldbart, School of Physics, Georgia Tech

“Heterogeneous Solids and the Micro/Macro Connection: Structure and Elasticity in Architecturally Complex Media as Emergent Collective Phenomena”

Launched before the atomic hypothesis held sway, the conventional theory of elasticity is a spectacular intellectual achievement. A continuum-level theory, it furnishes scientists and engineers with a powerful, internally consistent toolkit for determining how architecturally simple (i.e., regular) solid media such as

crystals respond macroscopically to imposed stresses, whilst encoding the underlying microscopic details of the atomic realm economically, via a handful of numerical parameters. Solids that are architecturally complex (i.e., irregular) at the atomic or molecular level, such as vulcanized rubber, gels and glasses, are commonly addressed using conventional elasticity theory. However, the irregularity of these media at the microscopic level raises new issues, not only of elasticity but also of structure: In what way do the elastic constants of such media fluctuate across a sample? Do such media strain non-affinely in response to imposed stresses? Are there regional variations in the thermal position-fluctuations of the constituent atoms? And, more generally, can the structure and elasticity of architecturally complex solids be viewed as emergent collective phenomena, determinable from their underlying, microscopic thermal motion and characterizable by some suitable continuum theory?

In this talk, I shall explain the essential elements of a seminal, microscopic approach to the physical properties of architecturally complex media, pioneered by Sam Edwards in the mid-1970s, which has fathered our modern continuum-based notions of structure and elasticity for irregular solids. At the heart of this microscopic approach is an extension of statistical mechanics that enables the handling of architecturally complex media, with their two distinct classes of microscopic random variables: the (equilibrating) atomic coordinates and the (fixed) descriptors of the architectural complexity. Edwards' bold extrapolation hints at a continuum theory for complex media whose mathematical form would be hard to divine without this microscopic intervention. In particular, the fields of this continuum theory inhabit a strange world, in that they depend on a continuously tunable number of copies of the three-dimensional position-vector. Moreover, this curious tunability has the virtue of permitting the encoding and determination of detailed information about the emergent, spatially heterogeneous structure and elasticity of complex solids. This information embodies the physically natural notion that the structure and elasticity of complex solids should be characterized not by constant parameters but by statistical distributions. The circle of ideas that I shall discuss provides a striking example of a setting in which microscopic notions are catalyzing developments in continuum theory that would be hard to conceive of without first descending to the microscopic realm.

Sound Bites I: Soft Condensed Matter and Polymers

Kenneth Desmond, Emory

"Designing a Shear Cell for Quasi-2D Emulsions"

We are designing an experiment to apply pure shear to a system of quasi-two-dimensional frictionless disks above the jamming point to study the relationship between microscopic rearrangements and microscopic stresses. Our frictionless disks will be oil-in-water emulsion droplets confined between two parallel plates. To apply pure shear we will compress the system of droplets in one direction while allowing the system to dilate in the perpendicular direction by an amount that conserves the area. Using algorithms we previously developed we will be able to identify the motion of each droplet and the forces between droplets in contact during the shearing process. We will also have control over the area fraction to measure how the microscopic details change with distance to the jamming point.

Gary Hunter, Emory

"Effect of Boundary Mobility on the Dynamics of Confined Colloidal Suspensions"

We use high-speed confocal microscopy to study the influence of boundary mobility on the dynamics of confined colloidal suspensions. Experiments in molecular super-cooled liquids show that confinement can enhance or hinder sample mobility, depending on whether the confining boundary is "soft" (mobile) or "hard" (immobile). We confine suspensions of PMMA microspheres within emulsion droplets of different sizes to examine the consequences of confinement. By changing the viscosity of the external, continuous phase, we also vary the boundary mobility of our samples. In this way, we decouple the effects of confinement and boundary mobility, and draw comparisons between colloidal suspensions and molecular liquids.

Juan Jose Lietor-Santos, Georgia Tech

"Bulk and Shear Moduli of Packed Microgel Suspensions"

We independently determine the bulk modulus of compressed microgel suspensions and of individual microgel particles and find that the elastic behavior of the suspension reflects the degree of compression of the particles. This feature, which is distinct from other soft materials like emulsions or foams, gives rise to an unusually large difference between the bulk and shear moduli of the suspension.

Hongzhi Wang, Georgia Tech

“Effects of Dipole Fields and Image Forces on Pickering Emulsions”

Interests in Pickering emulsions have been spurred recently due to their capabilities to develop novel microcapsules. To obtain targeted emulsion-templated microcapsules, the prerequisite is to achieve stable Pickering emulsions of desirable types. But unfortunately, our current understanding of emulsions stabilized with colloidal particles is far from satisfactory to predict reliably the type and the stability of Pickering emulsions, leading to complexities of emulsification with colloid particles. Our work will argue the electrostatic interactions have great effect on the formation and stability of Pickering emulsions and will investigate their effects through experimentally and theoretically studying emulsions with ionizable polystyrene particles. Our results suggest the electrostatic image force can hinder the particle adsorption to the interface and lead to no emulsions; and the electrostatic dipole formed due to asymmetric counterions at the interface can shift the equilibrium position of particle and lead to emulsions of anti-bancroft type.

John Hyatt, Georgia Tech

“Microgel Suspensions Studied Using Cross-Correlation Light Scattering”

I'm interested in studying the behavior of densely packed microgels that swell or deswell depending on temperature and pH of the surrounding solvent. Cross-correlation light scattering is one of the tools used to examine these particles. A challenge of this has been that the scattering function decays quickly, so high intensities are needed to obtain good data. However, high enough intensities cause the photodetectors to give erroneous results due to what is called the detector "dead time," where the detector ignores photons within a small timeframe after it has detected one. I'm going to briefly discuss 3D cross-correlation light scattering and these detector errors and compare data that has been corrected for them with uncorrected data.

Hsiang-Chih Chiu, Georgia Tech

“The Impact of Defects on Frictional Properties of Carbon Nanotubes”

Carbon nanotubes (CNT) are well known for their exceptional physical properties and have potential applications in micro and nano-electro-mechanical systems. Their exceptional mechanical properties and high aspect ratio also qualify them for mechanical reinforcements in composite materials. For all these applications, CNTs have to come in contact with their supporting surfaces, therefore it is imperative to understand their frictional properties. Previously, we found that when an AFM tip is sliding on top of a supported multiwall CNT along a direction in parallel or transverse to its axis, there exists a larger friction coefficient in the transverse sliding direction. This is explained by a soft "hindered rolling" of the CNT when the tip slides in the transverse direction and an additional friction dissipation channel, which is partially absent in the other sliding direction that leads to the friction anisotropy. Now in this work, we investigate the frictional properties of CNTs grown by the Arc discharged (AD) and Chemical Vapor Deposition (CVD) methods, the latter having more defects than the former, in order to study the impact of defects on their frictional properties. We find that the presence of defects in CNTs will increase the magnitudes of friction forces in both sliding directions and will also cause strong coupling of the transverse and longitudinal motions during tip sliding, giving rise to variations in the friction anisotropy. For the AD CNTs with minimum defects, a large friction anisotropy of 13.7 is found. However, for the CVD CNTs with more defects, the friction anisotropy drops to only 2.

Hassan Masoud, Georgia Tech

“Fast release of Nanoparticles from Microgel Capsules”

We develop a particle-based computational model to explicitly simulate the mechanics and transport properties of polymer gels, i.e. cross-linked polymer networks immersed in Newtonian fluids. Our hybrid numerical approach consists of a bond-bending lattice spring model to capture the micromechanics of random networks of interconnected elastic filaments and the dissipative particle dynamics to explicitly model the viscous fluid and diffusive objects. We use our mesoscale model to examine mechanisms for controlled release of nanoparticles enclosed within microgel capsules. We show that the capsule swelling results in a steady particle release, with a relatively slow release rate that is set by the diffusion through the network. We also demonstrate that the fluid flow through the capsule's membrane during deswelling leads to a rapid particle release. This release, however, is limited as network mesh size decreases when capsule shrinks. To enhance the rapid release from the deswelling capsule, we introduce solid microstructures, e.g. rigid microrods, inside the capsule. The length of the rods is comparable to the capsule internal diameter and the rod radius is comparable to the size of nanoparticles. The rods stretch the membrane of deswelled capsule and promote formation of larger pores, which allow rapid and

massive release of nanoparticles. Our findings reveal a new approach for regulating the release from micro-carriers by controllably changing the pore size. Furthermore, our three dimensional fully-coupled model of the cross-linked polymer networks provides a foundation for future studies of a broad range of problems in engineering, medicine, and biology that involve active and responsive polymer gels.

Justin Pye, Emory

“Evidence for Two Simultaneous Mechanisms Causing Tg Reductions in High Molecular-Weight Free-Standing Films Observed as Dual Glass Transitions in a Single Film”

Glass transition temperature (T_g) changes seen in nanoconfined polymer films have been well documented over the past 15+ years. Supported films exhibit a molecular-weight (MW) independent T_g reduction that manifests itself as a gradient in dynamics emanating from the free surface. Low MW free-standing films show qualitatively the same T_g reduction as supported films, but with the presence of two free surfaces resulting in a T_g reduction that is twice as large for a given film thickness. In contrast, high MW free-standing films exhibit a qualitatively different behavior with a linear reduction in T_g that is MW dependent, potentially described by de Gennes' sliding mode theory. These observations suggest that there may exist two separate mechanisms which can propagate enhanced mobility from the free surface into the film. With ellipsometry measurements over an extended temperature range, we have observed two reduced T_gs more than 30 K apart in individual high MW free-standing polystyrene films suggesting that both mechanisms act simultaneously within a film. These results may explain recent studies on high MW free-standing films using different experimental techniques that contradict the original literature.

Laura Gray, Emory

“Effect of Quench Conditions on the Subsequent Physical Aging Rate of Polymer Glasses”

We investigate the stability of polymer glasses when thermally quenched under different conditions. Ellipsometry is used to measure the physical aging rate of polystyrene (PS) films supported or transferred onto silicon wafers. The aging rate quantifies the time-dependent decrease in film thickness that results from the increase in average film density during aging. Although all films are subsequently aged in a supported state, we observe significant differences between films quenched in a free-standing compared to supported state. Films quenched in a free-standing state exhibit a strong thickness dependence to their physical aging rate at micron length scales, an order of magnitude or two larger than thicknesses where nanoconfinement effects on the glass transition and modulus are typically observed. In contrast, supported films do not display any film thickness dependence to their aging rate at this large length scale. This indicates that the physical aging of the material is strongly dependent on conditions during the formation of the glassy state. In an effort to determine the key factors underlying the aging dynamics, we have measured the physical aging rate of supported PS films quenched at various controlled rates. In addition, we have explored the effects of quenching free-standing films held on different frames such that either biaxial or uniaxial stress is applied.

Matthew Kincer, Georgia Tech

“Polymeric Templating and Alignment of Fullerenes”

Fullerene research has advanced to elevated levels in a short period of time due to the unique chemical and physical properties of the caged molecule that have been utilized in numerous applications. Due to the spherical shape of the fullerene molecule which allows for a hollow cavity, encapsulation of atoms or small molecules can occur within the ball structure. This encapsulation creates an endohedral component that is limited from interacting with other molecules which creates potential of control over electronic information of the isolated molecule. Endohedral fullerenes have the potential as serving as the base unit in a quantum computer if control over global alignment is attained. This research investigates the ability to use self-assembling strategies to obtain controlled alignment using a methods including ordering within a cylindrical forming co-polymer matrix, forming a supramolecular polymer complex with cyclodextrin molecules, and encapsulation within helical wrap of s-PMMA polymer chains. The ultimate goal is to understand the dynamics that control association and orientation of varying fullerene-based molecules in each strategy in order to maximize the alignment obtained of endohedral elements.

Sven Behrens, Georgia Tech

“New Applications for Polymers with Switchable Solubility”

We use polymers with pH-switchable solubility to synthesize stimulus-responsive colloidal particles, which can easily be assembled at solid-liquid and liquid-liquid interfaces and serve as a crucial design component in the fabrication of different types of microcapsules for controlled release applications and of substrates and particles with tunable roughness and wetting properties.

Khalid Salaita, Emory

“Mechanics of Intermembrane Junctions”

We are interested in developing materials to manipulate and characterize cell surface receptors. The central hypothesis is that the signaling functions of many membrane receptor is heavily influenced by biophysical inputs such as receptor geometry, spatial localization, clustering, and mechanical strain. In this short sound bite, I will highlight our recent progress at developing new methods to measure mechanical tension across specific cell surface proteins.

Stephanie Lin, Georgia Tech

“Crystallization Kinetics of Cellulose-Based Nanocomposites”

This research seeks to process and characterize cellulose-based nanocomposites to further explore the structure-property design space available in these materials available through an understanding of polymer nucleation and crystallization processes in the presence of nanoparticles. Specifically, the research will be structured to understand the impact of high aspect ratio cellulose nanocrystals on the crystallization kinetics of the semicrystalline biopolymer matrix polyhydroxybutyrate (PHB), with the goal of increasing the modulus and toughness concomitantly. If successful, this research will lead to the development of new materials with reduced environmental impact and unique combinations of properties that are unavailable in other materials.

Rudra Choudhury, Georgia Tech

“Polymer Chain Dynamics Determined by Solid-State NMR and Correlated with Enhanced Barrier Properties”

Nuclear magnetic resonance (NMR) is not just a spectroscopic technique for determination of molecular structure. This sound bite will describe how solid state NMR techniques are used to examine chain dynamics of solid polymer to correlate its enhanced barrier properties. Poly(ethylene terephthalate) (PET) films filled with different low molecular weight additives or after annealing above the glass transition temperature showed decrease of chain segmental dynamics using ¹³C solid-state NMR measurements. The observed changes in segmental dynamics can be correlated with reduced CO₂ and O₂ permeability in these modified PET samples. Relaxation times in the rotating-frame, ¹H-¹³C cross-polarization transfer time and Centerband-Only Detection of Exchange (CODEX) experiments were conducted to study the segmental mobility of the polymer chain of these samples over a wide range of frequencies which are distributed from mid-kilohertz to hertz range.

Xuxia Yao, Georgia Tech

“Prediction of Flow Behavior of Chromonic Liquid Crystals”

Lyotropic chromonic liquid crystals are a relatively new class of liquid crystals. They consist of many dyes and drugs. These dye or drug molecules dissolve in water easily and form pi-pi stacks/aggregates/columns. In this presentation, the aspect ratio of columns was calculated based on research in the literature. Order parameters, both $\langle p_{200} \rangle$ and $\langle p_{400} \rangle$ were calculated based on polarized Raman scattering experiment. By using the aspect ratio and order parameters, the tumbling parameter was calculated and flow behavior under steady shear was predicted.

Sound Bites II: Biological Matter and Flexible Devices**Sarah Steinmetz, Georgia Tech**

“Muscle Activation Strategy in Swimming Sandfish Influenced by Granular Drag Force”

A recent kinematic study has revealed that the sandfish utilizes a wave of body undulation during swimming that is independent of both material compaction and depth. To investigate how the sandfish accommodates different external medium conditions, we use high speed x-ray and visible light imaging with synchronized electromyogram (EMG) recordings of epaxial muscle activity during locomotion. During subsurface sand-swimming, EMG recordings reveal a uniphasic anterior-to-posterior traveling wave of muscle activation which travels faster than the kinematic wave. Muscle activation intensity increases as the animal moves deeper into the material but is independent of the frequency of movement; these findings are in accord with empirical force measurements which show that resistance force increases linearly with depth but are independent of speed due to the noninertial friction-dominated forces within a granular substrate. Muscle activation intensity only changes slightly (~10%) between a closely and loosely packed medium, likely a result of local changes surrounding the sandfish and/or differences in the

angle of entry. Overall, the difference in the EMG pattern as compared to other undulatory swimmers can be attributed to the unique physics of the granular media in which the sandfish interacts.

Andrew Masse, Georgia Tech

“Vertical Position Control in a Bioinspired Sand-Swimming Robot”

Sub-surface locomotion of the desert dwelling sandfish lizard has been modeled computationally via computer simulation, and physically in a limbless sand-swimming robot. In the latter model, lift and drag forces on the robot have been investigated experimentally, dragging different head shapes through granular media varying head wedge angle α , and wedge vertex location (as a fraction of head height h). Head shape effects on lift observed in these isolated drag experiments are in accordance with lift/drag effects seen when using the various head shapes in the sand-swimming robot. Using different geometries, lift forces could be modulated without substantially changing the magnitude of the drag forces. With the addition of a head tilt motor in the robot, we set out to provide a mechanism for active lift modulation. This work has created a sand-swimming robot with the ability to bury, maintain a fixed depth, or surface out of the media. Ultimately, this work could be used to develop a sand-swimming robot with the ability to follow any arbitrary route through granular media.

Tung Le, Georgia Tech

“Dynamics of Sequence-Dependent DNA Bending”

Bending or looping of double-stranded DNA is known to occur on a short-length scale (~ 50 nm) and is thought to be important in gene regulation and DNA packaging. Although formation of DNA loops have been analyzed previously by DNA ligation and AFM imaging, the kinetics of spontaneous DNA looping has not been measured. We are measuring the looping kinetics of short DNA duplexes (~ 150 bp) using fluorescence resonance energy transfer (FRET). By studying how the looping dynamics depends on DNA sequence, DNA length, and ion concentration, we will be able to learn the physical principles that govern conformational dynamics of DNA at short length scales.

Daniel Kovari, Georgia Tech

“A Novel Force Assay to Quantify Contractile Forces during Phagocytosis”

We have designed a biophysical assay to quantify the contractile forces during phagocytosis, and relate them back to the well-established, molecular events during the particle uptake. To measure phagocytic contractile force, we have designed soft, squishy particles whose mechanical deformations, when calibrated, can be used to estimate the applied force. The deformable particles, which are multi-layer polyelectrolyte microcapsules, are coated with IgG and characterized using an atomic force microscope to estimate their elastic modulus. Our studies show that microcapsule deformations are linear with force up to a maximal force limit (~ 150 nN), at which point the microcapsules undergo a buckling instability, collapsing irreversibly. We have studied the phagocytosis of the microcapsules by J774 macrophages both on surfaces and with a micropipette aspiration device. Experiments show that the microcapsules undergo deformation when ingested by surface-plated cells; further during phagocytosis or shortly thereafter, the microcapsules collapse. This indicates that the particles experience a minimal force of at least ~ 150 nN. Preliminary experiments show that phagocytosis is initiated almost immediately after contact between the capsule and the cell. However, little particle deformation is visible during the uptake, and unexpectedly, the capsules do not collapse. This suggests that the phagocytic forces exerted by suspended macrophages are less than those of adhered cells.

Louis McLane, Georgia Tech

“Mechanical Measurements of the Pericellular Coat”

The goal of our research is to characterize the mechanical properties of the pericellular coat (PCC) of cells. The PCC is a grafted polymer matrix surrounding most mammalian cells consisting of polysaccharides and proteins. It is produced at the surface of the cell membrane and extruded out in to the extracellular region. In many cases (such as in chondrocytes), one of the most important structural components is hyaluronan, a large extremely hydrophilic glycosaminoglycan. Its special physical properties and their tailoring by specialized hyaluronan binding proteins create tissue specific PCCs which are designed for local functionality. The cell coat is connected with many different physiological processes including cell migration, wound healing, cell proliferation, and the development of cancerous cells. Gaining a greater understanding of the PCC may give further insight into its role in these processes. We use a combination of optical tweezer force measurements and various microscopy techniques in order to characterize this coat on rat chondrocyte cells. Optical tweezers (OT) use highly focused laser beams in order to trap small, micron-sized objects. In addition to giving the ability to trap and manipulate objects, OT also act as force probes. Here we trap small polystyrene beads and then use these beads to perform force probe

experiments on our cell coat. The resulting force curves are then compared to theoretical polymer physics models in order to gain information about the structure of the PCC. We also use fluorescent tags and other microscopy techniques in order to help visualize the coat, which is invisible in normal bright field microscopy.

Gabriel Mitchell, Georgia Tech

“Biophysical Models of Enzymatic Lysis”

Enzymatic lysis of cells due to cleavage of bonds in cell walls mediates many basic biological processes and plays an important role in a number of biotechnological and medical applications. For example, researchers have begun to investigate the therapeutic potential of naturally occurring lytic enzymes as an alternative to traditional antibiotics. However, direct characterization of lytic enzymes using techniques based on synthetic substrates is often difficult because lytic enzymes bind to the complex superstructure of intact cell walls. We recently developed a new standard for the analysis of lytic enzymes based on turbidity assays which allow us to probe the dynamics of lysis without preparing a synthetic substrate. (Mitchell et al. *Physical Biology* 7:046002 2010). By measuring how lytic enzymes chemically clear a cloudy solution of living bacteria, we are able to predict the cell-level processes underlying bacterial death along with the susceptibility of bacteria to be killed in the first place. However, enzymatic lysis as a mechanical process remains poorly understood so that the effectiveness of the aforementioned inference process currently depends on strictly phenomenological and essentially ad-hoc descriptions of the mechanics of lysis. To address this problem we develop a biophysical model of enzymatic lysis incorporating the deterioration of the cell wall due to bond cleavage and the subsequent response of the inner membrane and cytoplasm. In doing so we offer a means of extending the analysis of indirect turbidity assays to probe the chemical activity of lytic enzymes between enzyme classes and across multiple cell cultures.

Jan Scrimgeour, Georgia Tech

“Microfluidic Dialysis Cell for Characterization of Macromolecule Interactions”

Responsiveness is an increasingly important material property in understanding native biomaterials and in the design of biomimetic "smart" materials. We present a microfluidic dialysis cell designed to facilitate the analysis of macromolecule interactions in responsive materials. Through the introduction of a rigid dialysis membrane, with a low molecular weight cut-off, into a microfluidic device we achieve long term retention of samples while allowing timely changes to be made in the sample's supporting solvent. The dialysis membranes, fabricated by coating a porous solid-state membrane with a thin layer of hydrogel, effectively suppress fluid flow in the sample allowing analysis of molecular interactions to be carried out using fluorescence recovery after photobleaching and other microscopy techniques. Measurements of pH-sensitive binding between the protein/polysaccharide pair, neurocan and hyaluronan components of the extracellular matrix in the central nervous system, demonstrate the integration of macromolecule retention, solvent switching and fluorescence recovery after photobleaching.

Keith Carroll, Georgia Tech

“ThermoChemical Nanolithography: Applications for Studying Heat Transfer”

Nanolithography techniques provide a wide range of applications for electronics, nanotechnology, biotechnology, and biophysics. We have developed a new technique called Thermochemical Nanolithography (TCNL), which offers an affordable, reliable lithographic technique capable of attaining high-resolution (~12 nm) patterning. TCNL is a method, in which the surface can be selectively functionalized through the use of an Atomic Force Microscope (AFM), and a specialized AFM tip made from highly doped semi-conductor material. By running a voltage across the tip we can heat the tip in a controllable manner. The heated tip can then be used to pattern a surface that has been coated with a polymer containing a thermally labile protecting group, and subsequently expose chemically active sites. The chemically active areas act as a template to which we can site-specifically bind molecules. We have demonstrated complex designs, large scale patterns, multichemistry capabilities, fast speeds, and nanometer resolutions (sub 15 nm). Our current work is focused on gradients, heat transfer to the polymer surface, and deprotection rates. The demonstrated properties of TCNL make it an attractive candidate for a myriad of nanotechnology experiments.

Suenne Kim, Georgia Tech

“Direct Fabrication of Arbitrary-Shaped Ferroelectric Nanostructures on Plastic, Glass, and Silicon Substrates”

We report a CMOS compatible method for the direct fabrication of arbitrary-shaped $\text{Pb}(\text{Zr}_{0.52}\text{Ti}_{0.48})\text{O}_3$ and PbTiO_3 ferroelectric nanostructures on a variety of substrates ranging from plastic (Kapton) to silicon and soda-lime glass. A heated nano-tip is used to induce nanoscale crystallization of sol-gel precursor

films. Ferroelectric lines with widths ≥ 30 nm, spheres with diameters ≥ 10 nm and densities up to 213 Gb/in² are produced.

Mauricio Bedoya, Georgia Tech

“Solution-Gating of Epitaxial Graphene for Chemical Sensing”

Epitaxial graphene can be used as the conducting channel of a Solution-Gated Field-Effect Transistor (SGFET). In this device, the graphene acts as the channel and a target molecule or analyte is dissolved in a buffer solution in contact with the graphene. The gate of an SGFET is an electrode that is in contact with the solution. The conductance of the channel is sensitive to the concentration of the analyte and to the gate-voltage. We present some results of the gate-voltage dependence of the conductivity of a SGFET based on graphene with KCl solutions of different ionic strengths.

Sound Bites III: Fluids and Grains

Annie Lesiak, Georgia Tech

“Phase Diagram of Water from computer Simulations”

Molecular dynamics simulations are used to compute (1) melting point and latent heat of fusion of the hexagonal crystal form of ordinary ice, and (2) the stability limits of both the solid and liquid phase. Calculations are based on the use of the TIP3P model. Melting parameters and stability limits are computed at pressures ranging from 1 atm to 2000 atm. The long-term goal of this project is studying the physical properties of liquid water in the supercooled state.

Neus Vilanova, Georgia Tech

“Droplet Size Control in Electro co-Flow”

Gaining control over the polydispersity and droplet size of emulsions is of great importance in different fields, such as pharmaceutical and cosmetic applications, among others. Microfluidic technology provides a better control over the droplet size compared to other conventional emulsification methods and usually gives monodisperse emulsions. However droplets below few microns are difficult to obtain using conventional microfluidic techniques such as T-junction, coflow, and flow-focusing methods, mainly due to the geometric limitations of the devices. The aim of this work is to obtain droplets in the micron and sub-micron range by applying electric fields in a co-flow geometry. In these experiments, we use three immiscible liquids, an outer dielectric liquid, an inner conducting liquid, and another conducting liquid (collector liquid) which acts as a counter-electrode. Depending on the applied voltage three different regimes of operation are distinguished: dripping, electro-dripping and an electrically dominated regime. In the later, the electric field is able to deform the liquid meniscus into a conical shape, also referred as Taylor cone, and the apex of the cone opens into a jet which is the source of the small droplets. The balance forces in each regime quantify how the droplet size changes. We observed that the droplets cross the counter-electrode interface and remain in the collector liquid; as a result a water-in-oil (W/O) emulsion is formed.

Venkata Gundabala, Georgia Tech

“Whipping in Electro-Coflow”

Applying electric fields onto a conducting liquid in a glass-based microfluidic device with an external coflowing liquid allows steady generation of sub-micron droplets and facilitates fundamental studies on the mechanism of drop formation and on the various modes of operation. We characterize one such mode of operation, called the Whipping mode, through high speed imaging technique. We find an interesting behavior of the whipping velocity as a function of inner flow rate and applied voltage.

Ekapop Pairam, Georgia Tech

“Stabilization of Toroidal and Higher Genus droplets Using Viscoelastic Media”

Without any force to counter the surface tension Newtonian liquid droplets are inevitably driven into spherical shaped. Toroidal and higher genus shaped droplets made up of Newtonian liquid, without external force, are unstable if suspended in another Newtonian liquid. In order to counter against the instability driven by surface tension while at the same time being able to utilized the liquid drag to generate the toroidal droplet we replaced the surrounding liquid with shear thinning Viscoelastic media. In the end we are able to reach a condition where we can stabilized droplets of non zero genus.

Kazem Edmond, Emory

“Decoupling of Rotational and Translational Diffusion in Supercooled Colloidal Fluids”

Using high-speed confocal microscopy, we directly observe the three-dimensional rotational dynamics of rigid clusters of microspheres suspended in dense colloidal suspensions. The clusters are highly ordered packings of fluorescently-labeled PMMA particles, fabricated using a recently developed emulsification technique. Our colloidal suspensions serve as good approximations to hard-sphere fluids, while the clusters probe the system's local rotational and translational dynamics. Far from the colloidal liquid's glass transition, both rotational and translational motion of the clusters are purely Brownian. However, in the liquid's supercooled regime, we observe a decoupling between the two types of motion: rotational diffusion is tightly coupled to the liquid's bulk viscosity, while translational diffusion decouples. Our observation supports the notion that supercooled liquids are not merely liquids with large viscosities but that diffusion takes place by fundamentally changed mechanisms.

Deborah Ortiz, Georgia Tech

“Water Nano-Hydrodynamics: The Interplay between Interfacial Viscosity, Slip and Surface Chemistry”

The understanding and the ability to manipulate fluids at the nanoscale is a matter of continuously growing scientific and technological interest. Fluid flow in nano-confined geometries is relevant for biology, polymer science and geophysics. The applications range from gene sequencing to protein segregation, cell sorting, sensors, nanotribology and diffusion through porous media. Here, we present experiments which show how the boundary viscosity of water strongly depends on the wetting properties of the confining surfaces. This dependence is fully explained by considering water slippage at the non-moving solid surface. The boundary viscosity as a function of the gap size for six surfaces with different wettability is fitted with a modified form of the Newtonian definition of viscosity, which takes into consideration the fluid slip. This simple relationship can explain the viscosity measurements and permits us to extract a “slip parameter” for each investigated surface. This slip parameter is found to increase with the static contact angle of the solid surface, as expected from previous work, bringing further evidence of the relationship between viscosity and slip. Finally, the obtained slip parameter increases with the shearing rate with the same linear dependence in all the surfaces investigated here.

Nick Gravish, Georgia Tech

“Relaxation of Entangled Granular Piles”

Granular media with grains of sufficiently complex geometry, such as u-shaped particles, entangle with neighboring particles. Piles formed from these geometrically cohesive particles may be strengthened by such interparticle entanglement. We study the relaxation of free-standing vertical columns formed from u-shaped particles to determine how bulk strength is affected by particle geometry. U-shaped particles of barb length, l , and constant width, w , are used to form columns and experimentally we vary particle shape over a range $l/w = 0 - 1.125$. Columns are formed by pouring particles into a 4.45 cm diameter tube and then packing with vertical vibration at fixed amplitude and duration. Outer tube is then removed and free-standing columns are subjected to vertical vibration at fixed frequency of $f = 30$ Hz and variable peak acceleration, G . We image the side profile of the column and measure average column height in time. The characteristic column collapse time under vertical vibration, τ , scales like $\tau = (1/f) \exp(G_0 / G)$ where G_0 is a measure of the piles strength. G_0 is non-monotonic for increasing l/w and is maximum at $l/w = 0.375$. A simple model is proposed combining entanglement potential and packing that can explain the experimental results.

Chen Li, Georgia Tech

“Resistive Force Theory Explains Force Generation During Rotational Intrusion into Granular Media”

When legged locomotors move on granular media their limbs intrude into the substrate along paths more complicated than simple vertical or horizontal trajectories. To investigate force generation for paths more representative of typical limb-ground interaction, we rotated simple objects (plate, c-shaped leg) into granular media and measured the resulting resistive force, F , as a function of the angle, θ , from maximum penetration depth. For all objects, greatest F occurs not at maximum depth ($\theta = 0$) as expected from the linear dependence of force on depth for vertical penetration, but substantially earlier ($\theta < 0$). The location and magnitude of maximum F depend on intruder geometry. We apply granular resistive force theory by measuring force on a plate as a function of orientation and direction of motion, to explain our observation of anisotropic force during rotational intrusion. Our data suggest that in granular media, larger yield stresses at fixed depth and with the same projected intruder area can be obtained by adjusting intruder geometry to maximize normal stress. This in turn provides hypotheses for locomotion biology and guidance for design of legged robots and other mobile devices.

Yang Ding, Georgia Tech

“Kinematic Theory for a 3-Link Sand Swimmer”

Geometric control theory and bio-inspired experimentation are two widespread approaches to robotic locomotion, generally considered as distinct. In this paper, we combine the two paradigms to analyze sand-swimming, a form of burrowing employed by several desert species, including the sandfish lizard. Our (Ding, Maladen, and Goldman’s) previous investigation of this mode of locomotion has produced a comprehensive but computationally intensive model for the relevant physics. Here, by adopting principles from geometric mechanics, we identify symmetries in the system that minimize the number of simulator calls required to evaluate the system’s motion; we then combine these principles with our (Hatton and Choset’s) prior work in geometric mechanics to produce comprehensive visualizations of the system dynamics that allow for intuitive gait design and optimization.

Minsu Cha, Georgia Tech

“Dissolution Implication in Granular Media”

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