ABSTRACTS - INVITED TALKS

APRIL 18 (WEDNESDAY): STUDENT CENTER, THEATER

9:00 – 9:40 Randy Kamien, University of Pennsylvania.

The Topological Character of Smectics

Though the systematic use of topology to understand defects in ordered matter is now nearly 50 years old, the original work failed to completely characterize systems with broken translational order, i.e., crystals. Smectics are the simplest example of crystals and we have employed new mathematical tools to study and classify the allowed point and line defects in them. The theory reduces to the time-honored homotopy theory if we ignore the periodic order of the smectic but offers a refinement -- though the smectic can support all the defect structure and algebra of the nematic phase that sits above it, the defects have further structure that we have uncovered. This has allowed us to understand previously open puzzles, including the nature of composite dislocations in smectics.

9:40 – 10:20 Mark Bowick, Kavli Institute for Theoretical Physics, University of California, Santa Barbara.

Topology in Polar Flocking and Active Nematics

Active flocking on curved surfaces, such as the 2-sphere and the catenoid, exhibits dynamical symmetry breaking in the form of spontaneous flow, calculable inhomogeneous density patterns and long-wavelength propagating sound modes that get gapped by the curvature of the underlying substrate. Curvature and active flow together result in symmetry-protected topological modes that get localized to special geodesics on the surface. These modes are the analogue of edge states in electronic quantum Hall systems and provide unidirectional channels for information transport in the flock, robust against disorder and backscattering. Active nematics instead exhibit spontaneous motility of strength +1/2 disclinations and active torques that favor the motility-driven unbinding of defects. Despite the directed motion of defects, nematic order is stabilized by rotational noise at low enough activity. Within a perturbative treatment, active forces lower the effective defect-unbinding transition temperature.

10:50 – 11:30 Arjun Yodh, University of Pennsylvania.

Unusual Director Configurations and Diffusion Driven by Liquid Crystal Elastic Anisotropy

I will describe experiments that probe effects of twist elastic anisotropy in lyotropic chromonic liquid crystals (LCLCs) on the director configurations in cylinders/spheres and on particle diffusion. Time permitting, I will also describe measurements of LCLC “coffee rings” and of twist fluctuations in suspended spherical LC droplets.

11:30 – 12:10 Ileana Streinu, Smith College.

Geometric underpinnings of auxetic behavior

In materials science, auxetic behavior is characterized by negative Poisson's ratios. We have recently developed a purely geometric theory of auxetic behavior for periodic framework materials. In this talk I will present the main ideas (rooted in rigidity theory) as well as the algorithmic consequences, which lead to efficient methods for detecting the local (infinitesimal) behavior. The design of novel two dimensional auxetic structures is facilitated by our theory of expansive mechanisms, fully characterized as periodic pseudo-triangulations. I will conclude with some recent results for designing three dimensional auxetic structures. Joint work with Ciprian Borcea.

4:10 – 4:50 Martin van Hecke, Leiden University & Amolf.

Sequential Mechanical Metamaterials

Sequences of motions govern the morphological transitions of a wide variety of natural and man-made systems, while the ability to interpret time-ordered signals underlies future smart materials that can be (re)programmed and process information. Here we introduce two novel classes of mechanical metamaterials, that can (1) exhibit sequential output and (2) are sensitive to sequential input. To obtain metamaterials that translate a global uniform compression into a precise multistep pathway of reconfigurations, we combine strongly nonlinear mechanical elements with a multimodal hierarchical structure, and demonstrate multi-step reconfigurations of digitally manufactured metamaterials. To obtain metamaterials that are sensitive to a sequence of mechanical inputs, we introduce the notion of non-commuting metamaterials, and show their capability for storing and processing information. Our work establishes generic principles for infusing metamaterials with sequential input and output.

APRIL 19 (THURSDAY): MARCUS BUILDING, ROOMS 1116–1118

8:30 – 9:10 Xiaoming Mao, University of Michigan.

Fracturing of marginally stable structures: fiber networks and topological metamaterials

When conventional brittle materials break, long cracks form due to stress focusing at crack tips: a phenomenon explained by Griffith in the 1920s. In this talk, we will discuss two types of systems where the fracturing process is “unconventional”. The first type are fiber networks. Using simulations we found that stress concentration never occurs in these networks. Instead, the network enters a steady state where force chains break and reform, leading to a divergent length scale. The second type are Maxwell lattices with domain walls hosting topologically protected states of self stress. Our simulations showed that stress and bond breaking events are concentrated on these domain walls, even in presence of cracks and deep into the nonlinear process of fracturing. We discuss how these ideas can be used in designing metamaterials that are protected against crack formation.

9:10 – 9:50 Dave Weitz, Harvard University.

New Results for Old Physics: Critical Phenomena for Colloids in Microgravity

This talk will describe results from experiments conducted in the absence of gravitational forces allowing the effects very delicate interactions between colloidal particles to be explored. The behavior very close to the boundary of spinodal decomposition will be described.

11:10 – 11:50 Tim White, Air Force Research Laboratory.

Performance Derived from the Directed Self Assembly of Liquid Crystal Elastomers

A specific class of liquid crystalline polymeric materials referred to as liquid crystalline elastomers (LCEs) were predicted by de Gennes to have exceptional promise as artificial muscles, owing to the unique assimilation of anisotropy and elasticity. Subsequent experimental studies have confirmed the salient features of these materials, with respect to other forms of stimuli-responsive soft matter, are actuation cycles of up to 400% as well “soft elasticity” (stretch at minimal stress). In this presentation, I will summarize our recent efforts in developing materials chemistry amenable to directed self-assembly.

Enabled by these chemistries and processing methods, we have prepared LCEs with distinctive actuation and mechanical properties. Notably, these materials are homogenous in composition (lacking material/material interfaces).

11:50 – 12:30 Omar Saleh, University of California, Santa Barbara.

Self–assembled DNA liquids: Properties and protein activation

Biomolecules can self-assemble into liquid phases, termed 'membraneless organelles' in the biological context, though also known as 'coacervates'. I will discuss our efforts to study this by exploiting DNA nanotechnology to create DNA particles that phase separate into liquids. Formation of liquids, rather than gel aggregates, depends sensitively on the internal flexibility of the DNA particles. Our engineered system displays unusual properties, including the ability to create several distinct liquid phases in a single solution, and to tailor interactions between the phases. Further, the reduced valency of the particles, along with the relatively stiff nature of the constituent DNA strands, causes the liquid to be extraordinarily sparse, with a DNA volume fraction of only ~2%. This opens the possibility to activate the material by infusion of the liquid with proteins; I will discuss our initial attempts at doing this.

2:50 – 3:30 Younan Xia, Georgia Institute of Technology.

Symmetry Breaking during the Synthesis of Nanoparticles

Symmetry breaking is a ubiquitous phenomenon that occurs spontaneously when a system is subjected to variations in size and/or perturbations in terms of thermodynamic parameters. As a stochastic process, even small fluctuations acting on a system can arbitrarily push it downward one of the branches of a bifurcation. In this talk, we will use nanoparticle synthesis to illustrate the concept of symmetry breaking. Our aim is to convey its importance from a mechanistic perspective, by which one can rationally alter the experimental conditions to manipulate the growth pattern (symmetric vs. asymmetric) and thus generate colloidal nanoparticles with controlled shapes, structures, and properties for various applications, including the production of the famous Janus nanoparticles.

3:30 – 4:10 Ludovic Berthier, CNRS & University of Montpellier, France.

Ordered and disordered motion in dense active materials

We discuss how the non-equilibrium driving forces introduced by the natural biological activity or by physical self-propulsion mechanisms generically affect the structure, dynamics and phase behavior of dense active media. We use theory and computer simulations to analyze simple models of such active materials. We borrow concepts from the equilibrium physics of amorphous and crystalline materials to provide a physical understanding of experimental observations performed with more complex systems such as self-propelled colloidal and granular systems, biological tissues, and bacterial colonies.

APRIL 20 (FRIDAY): STUDENT CENTER, BALLROOM

8:30 – 9:10 Sid Nagel, University of Chicago.

Exploiting disorder

We are taught to understand solids by considering ideal crystals. This approach becomes untenable as the amount of disorder increases; for a glass with no well-defined long-range order, a crystal is an abysmal starting point for understanding the glass's rigidity and excitations. Is there an alternative – the opposite of a crystal – where order, rather than disorder is the perturbation? Jamming is an alternate way of creating rigid solids that are qualitatively different from crystals. In a crystal with one atom per unit cell, all atoms produce the same response to external perturbations. Jammed materials are not similarly constrained and a new principle emerges: independence of bond-level response. Using networks where individual bonds can be successively removed, one can drive the system to different regimes of behavior. Consequently, one can exploit disorder to achieve unique, varied, textured and tunable response from auxetic to allosteric behavior.

9:10 – 9:50 Paul Goldbart, Georgia Institute of Technology.

Some universal features of soft random solids

The aim of this talk is to look at soft random solids through the lens of condensed matter theory, and to explore how their core features -- most notably their random structure and elasticity –- emerge via the collective behavior of their constituents. Along the way, we shall see that, provided certain twists are added, a familiar kind of field theory reveals some universality and even some simplicity in these archetypes of complexity.

10:30 – 11:10 Olivier Dauchout, CNRS, Gulliver Lab.

Granular glasses: a real space insight into relaxation processes in glasses

Everyday life tells us that matter acquires rigidity when it is cooled down or compacted. This is not only the case for materials, which crystallize at low temperature or high pressure. It also happens for disordered media such as foams, emulsions, colloidal suspensions, granular media and glasses.

I will review what vibrated granular media experiments have told us about elementary excitations and relaxation processes in such disordered systems. More specifically, I will (i) discuss the connections between the glass and the jamming transition, (ii) illustrate the type of hierarchical dynamics, which controls granular glass relaxation and (iii) present recent results about a glass to glass transition, the so-called Gardner transition, of which we obtained recently the first experimental evidence. I will conclude by discussing the impact of this transition on the mechanical properties of such packings.

1:00 – 1:40 Françoise Brochard–Wyart, Institut Curie / UPMC.

Hybrid active matter: when particles and living cells play together

We describe cellular aggregate – nanoparticles systems, using both small particles which are digested by cells by endocytosis and phagocytosis, and large particles, which do not enter in the cells. Nanostickers: We show that nanoparticles can be used as a glue for cells to enable the formation of self-assembled aggregates and may have important applications for cellular therapy and cancer treatment. Microparticles: gluttonous cells. As cell aggregates spread on adhesive substrates decorated with microparticles, the cells at the periphery uptake the microparticles by phagocytosis, clearing the substrate and forming an aureole of cells full of particles. It allows to quantify the MP volume fraction incorporated by the cell.

1:40 – 2:20 Paul Chaikin, New York University.

Quantifying hidden order out of equilibrium

While the equilibrium properties, states, and phase transitions of interacting systems are well described by statistical mechanics, the lack of suitable state parameters has hindered the understanding of non-equilibrium phenomena in divers settings, from glasses to driven systems to biology. Here we introduce a simple idea enabling the quantification of organization in non-equilibrium and equilibrium systems, even when the form of order is unknown. The length of a losslessly compressed data file is a direct measure of its information content [1]. Here we use data compression to study several out-of-equilibrium systems, and show that it both identifies ordering and reveals critical behavior in dynamical phase transitions. Our technique should provide a quantitative measure of organization in systems ranging from condensed matter systems in and out of equilibrium, to cosmology, biology and possibly economic and social systems.

ABSTRACTS - CONTRIBUTED TALKS

APRIL 18 (WEDNESDAY): STUDENT CENTER, THEATER

2:50 – 3:50

Pavel Aprelev, Clemson University.

Title: Time-dependent local microrheology of clotting insect blood using magnetic rotational spectroscopy
Authors: Pavel Aprelev, Chadwick Walls, Bonni McKinney, Dr. Peter Adler, Dr. Konstantin Kornev

Abstract
Recent advances in the fields of soft and composite materials have led to the development of Magnetic Rotational Spectroscopy (MRS) – a technique for analysis of microrheological properties of complex fluids such as gels and polymer solutions. MRS requires minute amounts of material and thus allows for direct characterization of local viscosity and elasticity of highly anisotropic liquids. It relies on the rotation of ferromagnetic nanorods dispersed in the studied solution with a steadily rotating magnetic field. When the magnetic and the resistive torques affecting the nanorod are nearly the same, the system becomes very sensitive to even the smallest property changes. We have developed an experimental procedure to accurately control the external magnetic field and track the motion of the probes. Here, we discuss our application of this technique to study the changing rheological properties of highly anisotropic clotting insect blood.

Michael Dimitriyev, Georgia Institute of Technology.

Title: Geometry and mechanics of knitted fabric
Authors: Michael Dimitriyev & Elisabetta Matsumoto

Knitted fabric consists of yarn that is stitched together in a repeated pattern. The fabric is held together by internal stresses due to the large contortions of its threads, which are linked together in slipknots, placing physical constraints on thread displacement. The result is a material with extremely soft bending elasticity that is also able to stretch. Due to the complex structure of knitted fabrics, much is unknown about the collective mechanics of these materials and there is not currently an accurate constitutive model. As such, modeling is limited to computationally-intensive yarn-level simulations. Additionally, global properties of the fabric are sensitive to the local geometry of the stitches. We seek a set of constitutive relations for a variety of stitch patterns by examining the equilibrium stress distribution in a model of linked elastica, with the ultimate goal of developing a robust continuum theory.

Jessica Faubel, Georgia Institute of Technology.

Title: Biomimetic Hyaluronan Polymer Brush Grown from Enzymes
Authors: Jessica Faubel, Wenbin Wei, Nicholas Greenwald, Jennifer Washburn, Bruce Baggenstoss, Paul H. Weigel, and Jennifer E. Curtis

Polymer brushes are a versatile platform for performing fundamental studies of polymer physics, while also having the potential of designing functional surfaces with industrial and biomedical applications in mind. We present a novel platform to fabricate, characterize, and pattern hyaluronan-based polymer brushes at interfaces using the enzyme hyaluronan (HA) synthase. The brushes are microns thick, regenerative, easily tuned, and stimulus responsive. Their extreme thickness makes them amenable to unusual characterization techniques like direct visualization of the brush’s thickness, polymer concentration profile, and penetration by nanoparticles or proteins. The brushes are also patternable using a UV laser on a confocal microscope which allows for control of the HA synthase grafting density. This new experimental platform represents a unique approach to fabricating polymer brushes, distinct from the ubiquitous grafting to or from approaches, and will allow for a wide range of characterization studies.

William Savoie, Georgia Institute of Technology.

Title: Smarticle ensembles: collective capabilities of shape changing robots
Authors: William Savoie, Shengkai Li, Daniel I Goldman

We will talk about recent developments with simple robots or "smarticles". Smarticles are a three-link two degree of freedom system capable of modulating its body geometry. Our aim is to discover principles by which shape-changing active systems can perform tasks or goal-oriented behaviors. We will focus on two particular experiments we have performed. The first system looks at how interactions many, individually immobile robots, can utilize shape change as a collective to produce movement. The other system we will talk about focuses on the material properties of a many smarticle system by performing tests where we apply a strain and measure the stress response of a string of smarticles. By having the smarticles actively respond to an applied strain, a smarticle system can change its material properties.

Lorezo Rovigatti, Institute of Complex Systems (CNR-ISC) - Rome, Italy.

Title: Computer-generated realistic microgels
Authors: Lorenzo Rovigatti, Nicoletta Gnan and Emanuela Zaccarelli

Microgels are soft particles made by cross-linked polymer networks which are responsive to external control parameters such temperature or pH. The internal architecture and the temperature variations thus strongly affect effective interactions between microgels, especially at high densities. For these reasons, the simple Hertzian model for elastic spheres is only applicable to the fluid regime [1]. In order to go beyond this simplified picture, we have recently synthesized microgels in-silico using different preparation protocols [2]. In this talk I will discuss the internal properties of these particles in relation to available experimental data for varying softness and temperature with the aim to provide a realistic model that will be used to determine more accurate effective interactions. [1] D. Paloli et al. , Soft Matter 9, 3000 (2013). 2] N. Gnan, L. Rovigatti and E. Zaccarelli, Macromolecules 50, 8777(2017); J. Phys.: Condens. Matter 30, 044001 (2017)

APRIL 19 (THURSDAY): MARCUS BUILDING, ROOMS 1116–1118

10:20 – 11:10

Guram Gogia, Emory University.

Title: Emergent Bistable Switching in a Nonequilibrium Crystal
Authors: Guram Gogia & Justin Burton

Multistability is a ubiquitous feature of many physical, chemical and biological systems that are driven far from equilibrium. In nonequilibrium systems made of bistable elements, such as neural networks, global bistability is a common feature so that the entire system can switch behavior. Nevertheless, here we experimentally demonstrate that such "life-like" behavior can be observed in simple physical systems. We observe temporal switching between a crystalline, condensed state and a gas-like, excited state in a spatially-extended, quasi-two-dimensional layer of charged microparticles. We confirm our results using molecular dynamics simulations, which show that conservative forces, damping, and stochastic noise are sufficient to induce switching over a broad range of time scales, from seconds to hours. In addition, we find that variations in particles sizes are the nucleation seeds of switching. Specifically, quenched disorder leads to anharmonic vibrational modes with low participation ratios that facilitate system-wide thermalization.

Yoav Green, Harvard University.

Title: Inference of mechanical stresses within the actively migrating cell sheet
Authors: Yoav Green, Jeff Fredberg and James Butler

Collective migration of epithelial cells is important in development, wound healing, and cancer invasion. These cells typically comprise confluent monolayers, within which internal stresses are supported through cell/cell and cell/substrate interactions, the latter providing propulsive forces, or tractions. We have shown [1] that given the tractions, the 2D in-plane stresses within the layer can be recovered numerically through Monolayer Stress Microscopy. Here we revisit this problem and find analytical expressions for the relationship of tractions, through velocities/displacements, to stresses; these expressions do not suffer from numerical complexities and uncertainties. Independent of whether a motility force is included or not, our model predicts a velocity-traction relation different from strict proportionality (such as simple viscous friction) as has been commonly assumed[2,3]. [1] Tambe et al., Nat. Mat. (2011)[2] Basan et al, PNAS, (2013)[3] Banerjee et al, PRL (2015)

Shane Jacobeen, Georgia Institute of Technology.

Title: Cellular packing, mechanical stress and the evolution of multicellularity.
Authors: Shane Jacobeen, Jennifer T. Pentz, Elyes C. Graba, Colin G. Brandys, William C. Ratcliff, and Peter J. Yunker

The evolution of multicellularity set the stage for sustained increases in organismal complexity. However, a fundamental aspect of this transition remains largely unknown: how do simple clusters of cells evolve increased size when confronted by forces capable of breaking intracellular bonds? Here we show that multicellular snowflake yeast clusters fracture due to crowding-induced mechanical stress. Over seven weeks (~291 generations) of daily selection for large size, snowflake clusters evolve to increase their radius 1.7-fold by reducing the accumulation of internal stress. During this period, cells within the clusters evolve to be more elongated, concomitant with a decrease in the cellular volume fraction of the clusters. The associated increase in free space reduces the internal stress caused by cellular growth, thus delaying fracture and increasing cluster size. This work demonstrates how readily natural selection finds simple, physical solutions to spatial constraints that limit the evolution of group size—a fundamental step in the evolution of multicellularity.

Shankar Lalitha Sridhar, University of Colorado Boulder.

Title: Mechanics of Active Networks – Lessons from Fire Ant Aggregations
Authors: Franck Vernerey[1], Alberto Fernandez-Nieves[2], Tong Shen[1], and Shankar Lalitha Sridhar[1]*(presenter).
[1]Mechanical Engineering, University of Colorado Boulder
[2]Dept of Physics, Georgia Institute of Technology

Biological assemblies in nature are seen as active matter due to their ability to perform intelligent collective motion based on neighbor interactions and sometimes without any centralized control or leadership. Fire ants are a great example in this context and display a rich class of material behaviors, including elasticity, viscous flow, and self-healing. Although classical theories in mechanics have enabled us to mechanically characterize this system, there is still a gap in our understanding on how individual ant behavior affects the emerging response of the aggregation. I will discuss an alternative approach from a statistical perspective where the population distribution of ants evolves due to mechanical deformation, and individual ant's leg detachment and attachment events. Numerical simulations of the aggregation's response in diverse situations, such as jamming (density) and shear thinning (reduced viscosity) will be presented and compared to experimental measurements.

2:00 – 2:50

James McInerney, Georgia Institute of Technology.

Title: How hidden geometric symmetries in origami generate new folding mechanisms
Authors: James McInerney, Zeb Rocklin

The traditional Japanese art of paper folding has inspired various foldable materials, some now realizable at the atomic scale. These thin sheets use engineered crease patterns to provide a desired mechanical response governed by the crease pattern geometry. We consider the entire class of triangulated origami, where global symmetries come paired with force-bearing modes that correspond to linear folding motions. We find triangulated origami generally has two such folding modes that extend into the non-linear regime and transform the origami sheet into cylindrical sections. The key feature of this class of origami is its matching number of constraints and degrees of freedom; hence, our methods are applicable to sheets allowing cuts and folds called kirigami, and continuous sheets satisfying this condition.

Jonathan Michel, Georgia Institute of Technology.

Title: Why is Structural Hierarchy So Prevalent in Biological Materials?
Authors: Jonathan Michel and Professor Peter Yunker

Structural hierarchy, in which materials possess distinct features on multiple length scales, is ubiquitous in nature. Many biological materials, such as bone, cellulose, and muscle, have as many as ten hierarchical levels. While structural hierarchy confers many mechanical advantages, including improved toughness and economy of material, it also presents a problem as each hierarchical level substantially increases the amount of information necessary for proper assembly. This seems to conflict with the broad prevalence of naturally occurring hierarchical structures. At the present, there is no general framework for understanding the interplay between structures on disparate length scales; such a framework is a critical tool for accounting for the robustness of hierarchical materials to defects. Here, we use simulations and experiments to validate a generalized model for the tensile stiffness of hierarchical, stretching-stabilized networks with a nested, dilute hexagonal lattice structure, and demonstrate that the stiffness of such networks becomes less sensitive to errors in assembly with additional levels of hierarchy. Following seminal work by Maxwell and others on criteria for stiff frames, we extend the concept of connectivity in network mechanics, and find a similar dependence of material stiffness upon each hierarchical level. More broadly, this work helps account for the success of hierarchical, filamentous materials in biology and materials design, and offers a heuristic for ensuring that desired material properties are achieved within the required tolerance.

David Rivas, Johns Hopkins University.

Title: Probing Active Nematic Films with Magnetically Manipulated Colloids
Authors: David Rivas and Dr. Robert Leheny

Active nematics are non-equilibrium liquid crystalline systems composed of self driven particles whose motility creates flows that lead to perpetual changes in the local nematic director. We employ magnetically manipulated microdisks and nanorods as local probes of quasi-2D active nematic films. By observing the hydrodynamic interactions between the probes and the films, we are able to obtain novel information about the mechanical and dynamical properties of the system.

Pierre Ronceray, Princeton University.

Title: Cell contraction induces long-ranged stress stiffening in the extracellular matrix
Authors: Pierre Ronceray, Yu Long Han, Martin Lenz, Chase Broedersz, Ming Guo

Animal cells in tissues are supported by biopolymer matrices, which exhibit highly nonlinear mechanical properties. Here we show that this nonlinearity allows living contractile cells to generate a massive stiffness gradient in three distinct 3D extracellular matrix model systems: collagen, fibrin, and Matrigel.

We decipher this remarkable behavior by introducing Nonlinear Stress Inference Microscopy (NSIM), a novel technique to infer stress fields in a 3D matrix from nonlinear microrheology measurement with optical tweezers. Using NSIM and simulations, we reveal a long-ranged propagation of cell-generated stresses resulting from local filament buckling. This slow decay of stress gives rise to the large spatial extent of the observed cell-induced matrix stiffness gradient, which could form a mechanism for mechanical communication between cells.

APRIL 20 (FRIDAY): STUDENT CENTER, BALLROOM

11:10 – 12:00

Cornelia Rosu, Georgia Institute of Technology.

Title: Soft, responsive and semiconducting gels
Authors: Cornelia Rosu,[1] Paul S. Russo[2,3] and Elsa Reichmanis[1,2,3]
[1]School of Chemical and Biomolecular Engineering, [2]School of Materials Science and Engineering, [3]School of Chemistry and Biochemistry, Georgia Institute of Technology, Atlanta, GA, 30332

Interaction of biopolymers with organic electronic materials provides an appealing opportunity to design electroactive materials for use in many applications especially bioelectronics. Because of their biocompatibility, polypeptides do not act just as simple bio- components; rather they effectively influence the organization of π-conjugated polymers into highly crystalline structures that allow charge transport. The talk will focus on poly(γ-benzyl-L-glutamate), PBLG, a synthetic polypeptide that forms thermoreversible tree-dimensional networks. Blends with poly(3-hexylthiophene), P3HT, resulted in gel materials able to switch reversibly on and off their photo-physical properties. This behavior was observed during two cycles of heating-cooling-aging. Enhanced alignment of P3HT chains into J-aggregate structures, ideal for effective electronic performance, was attributed to interactions between the PBLG benzyl side chains and P3HT hexyl arms.

Hemaa Selvakumar, Georgia Institute of Technology.

Title: Spatiotemporal dynamics of biofilm-phage interactions
Authors: Hemaa Selvakumar, Yu-Hui Lin, Joey Leung, Joshua Weitz and Jennifer Curtis

Biofilms are ubiquitous complex fluids formed by bacterial colonies which secrete and embed themselves in a protective polysaccharide matrix. The properties of the extracellular polymeric matrix and the density-dependent metabolism of bacteria confer drug-resistant properties to biofilms, rendering them infamously difficult to eliminate. One alternative strategy to disrupt biofilm infection is the use of bacteriophage, viruses that infect and kill bacteria while increasing in number via self-replication and bacterial lysis. The interaction of phage with freely swimming (planktonic) bacteria communities is well understood. However, the spread of phage and infection through heterogeneous biofilms remains unexamined. Both the initial spatial complexity of the bacterial distribution as well as the porous polymeric matrix is expected to impact the outcome. We study the spatiotemporal dynamics of biofilm-bacteriophage interactions through confocal microscopy experiments and simulations to gather insights into this active process.

Aghil Abed Zadeh, Duke University.

Title: Local and global avalanches in sheared granular materials
Authors: Aghil Abed Zadeh, Jonathan Barés, Robert Behringer

We perform a stick-slip experiment to characterize avalanches for granular materials. In our experiment, a constant speed stage pulls a slider which rests on a vertical bed of circular photoelastic particles in a 2D system. The stage is connected to the slider by a spring. We measure the force on the spring by a force sensor attached to the spring. We study the PDF of energy release and slip size, avalanche shape in time, and other seismicity laws during slip avalanches. We analyze the power spectrum of the force signal and probability distributions to understand the effect of the loading speed and of the spring stiffness on the statistical behavior of the system. From a more local point of view and by using a high speed camera and the photoelastic properties of our particles, we characterize the local stress change and flow of particles during avalanches. By image processing we detect the avalanches, as connected components in space and time, and the energy dissipation inside the granular medium and their PDFs. The PDFs of avalanches obey power laws both at global and local scales, but with different exponents. We try to understand the distribution and correlation of local avalanches in space and the way they coarse grain to the global avalanches.

Minxiang Zeng, Texas A&M University.

Title: Highly efficient oil-water separation using surface-programmable membranes
Authors: Minxiang (Glenn) Zeng, Eric Zhang, Dali Huang, Dr. Zhengdong Cheng

The challenge of separating emulsified oil from oil/water mixture has sparked enormous research interests in developing advanced membrane technology. One of the most crucial elements to achieve high separating efficiency lies in the design of unique interfacial properties of membranes. Herein, we present a surface-programmable membrane for separating oil-water emulsion based on contrast wetting strategy. Additionally, owing to the precise control on the surface chemistry and microstructures of membranes, the hybrid membrane not only separates the oil-water mixture with high efficiency (>99.2%), but also demonstrates versatility for multiple applications, e.g., heavy metal removal. This research opens up new opportunities in developing multifunctional membrane-based materials.

ABSTRACTS - POSTERS

APRIL 18 (WEDNESDAY): STUDENT CENTER, THEATER

12:10 – 2:50 (Poster Number in brackets)

[1] Gabi Steinbach, Georgia Institute of Technology.

Title: Gamble vs. strategy of microbial competitors - Interface tension and confinement in dense biofilms with T6SS contact-killing
Authors: Gabi Steinbach, David Yanni, Peter Yunker

We present a system of magnetic colloidal Janus particles as a tool to examine the role of aniotropic interactions in pattern formation and collective non-equilibrium dynamics on the mesoscale. The spherical particles exhibit a magnetic and a non-magnetic hemisphere. This provides the exceptional feature of an off-centered net magnetic moment. In experiments and simulations, we demonstrate how this anisotropy provides innovative flexibility in pattern formation and collective dynamics. First, the particles spontaneously self-assemble into branched structures as a result of a bistable assembly behavior. Second, this assembly is the starting point for a rich phase behavior under external magnetic fields. Third, the collective dynamics of the anisotropic particles has revealed a novel approach for magnetic actuation via internal rotations.

[2] Brian Khau, Georgia Institute of Technology.

Title: Utilizing ion-responsive colorimetric response of carboxylated polythiophenes for stimuli-responsive hydrogels
Authors: Brian Khau, Elsa Reichmanis, Paul Russo

The introduction of conjugated polymers into a static hydrogel network imparts responsiveness to environmental stimuli. In this work, poly [3-(potassium-4-butanoate)thiophene-2,5-diyl], exhibits a significant, unique colorimetric response to phosphate-based ions in the solution phase, due to twisting of the polythiophene backbone. To further utilize this behavior, the polymer is embedded into a chitosan-based hydrogel, resulting in a hybrid construct with mechanical properties similar to that found in the extracellular matrix common to most animals.

[3] Svetoslav Nikolov, Georgia Institute of Technology.

Title: Designing synthetic phagocyte-like microcapsules for particle capture
Authors: Svetoslav Nikolov, Alberto Fernandez-Nieves, Alexander Alexeev

In our work we leverage the large volume changes achieved during the volume-phase transition of hydrogels to create a model for a novel phagocyte-like device which is capable of selectively capturing, retaining, and expelling external nanoparticles dispersed throughout the solvent. In our mesoscale dissipative particle dynamics (DPD) model we place a spherical hydrogel network inside a rigid spherical shell with six symmetrically perforated holes. Upon application of an external stimulus the hydrogel network swells, expanding through the perforated holes in the shell, and contacting the external nanoparticle rich solution. Removal of the external stimulus causes the gel to retreat back into the shell interior, bringing in nanoparticles from the outside, in the process. By functionalizing a polymer brush around the perforated holes in the shell we are able to prevent the random diffusion of nanoparticles into the shell interior and better control the capture rate of our device.

[4] Chase Brisbois, Northwestern University.

Title: Actuation of Magnetoelastic Membranes in Dynamic Magnetic Fields
Authors: Chase A. Brisbois, Mykola Tasinkevych, Pablo Vázquez-Montejo, and Mónica Olvera de la Cruz

Abstract
Microrobotic applications in biological tissue require materials to operate at a wide range of length scales, under constant or variable temperature/pH environments, and without connection to an external power source. Magnetoelastic membranes composed of linked, superparamagnetic colloids meet many of these requirements; however, their synthesis and behavior are poorly understood. We present analytic solutions for membrane conformation alongside finite element analysis and coarse-grained molecular dynamics simulations to uncover the basic behavior of magnetoelastic membranes in precessing magnetic fields. We show how the magnetic field transmits forces that cause membranes to expand, collapse, twist or flatten. These basic concepts are scaleable and apply to micro- as well as macrorobotic systems. Furthermore, we suggest synthetic routes for free and load-bearing membranes.

[5] Andras Karsai, Georgia Institute of Technology.

Title: Highly Inertial Wheeled Locomotion in Dry Granular Media
Authors: Andras Karsai, Daniel I. Goldman

Abstract
We have developed an automated experimental setup for studying the dynamics of wheeled locomotion in dry granular substrates. The apparatus enables systematic tests of quasistatic rheological models of intruder-substrate interaction, such as Resistive Force Theory and Terramechanics, in fast, dynamic regimes where inertial effects can cause deviation from theory and changes in the rheological behavior. These transient effects showcase how time-independent models are insufficient for capturing high inertia wheeled locomotion.

[6] Bailey Risteen, Georgia Institute of Technology.

Title: Thermoresponsive liquid crystal templating of semiconducting polymers with cellulose nanocrystals
Authors: Bailey Risteen, Justin Zoppe, Mohan Srinivasaro, Paul Russo, Elsa Reichmanis

Abstract
One main challenge in producing flexible organic electronic devices is ensuring adequate performance of the active semiconducting polymer; the alignment of these polymers by intra- and interchain π-π stacking is crucial to achieving superior optoelectronic properties and a high charge-carrier mobility. In this work, the liquid crystal ordering of bio-derived cellulose nanocrystals (CNCs) was investigated as a means of enforcing long-range order in the semiconducting polymer poly[3-(potassium-4-butanoate) thiophene-2,5-diyl], PPBT. It was found that the inclusion of these renewable particles in PPBT solutions resulted in enhanced polymer chain alignment as confirmed by UV-Vis and circular dichroism spectroscopy. Furthermore, when the CNCs were decorated with a thermoresponsive polymer, poly(N-isopropylacrylamide) (PNIPAM), the liquid crystal phase, and therefore the semiconducting polymer ordering, could be switched “on” and “off” by changing the temperature.

[7] Dominic Robe, Emory University.

Title: Rearrangement Event Rates in Aging Colloidal Glass
Authors: Dominic Robe and Stefan Boettcher

Abstract
We examine the intermittent and heterogeneous dynamics of an aging colloidal glass using MD simulations. We find that the rate of cooperative rearrangement events and the times between events follow the statistics of record-breaking fluctuations of a stochastic random variable. We suggest this is

because the rearrangements are permitted by coincidental cooperation of degrees of freedom, and each rearrangement raises the threshold for required cooperation. We believe this perception of physical aging could apply to spin glasses, polymers, and other aging systems as well as colloids.

[8] Alyssa Blake, Georgia Institute of Technology.

Title: Probing the Jamming Transition using Stimuli Responsive Core-Shell Materials
Authors: Alyssa Blake and Paul Russo

Abstract
Silica polypeptide composite particles consisting of an inorganic, colloidal silica core and an organic polypeptide shell can be used as model systems for studying biological and physical particle interactions. The polypeptide shell can undergo secondary conformational transitions between an alpha helix and random coil conformation, which results in a stimuli responsive material. Jamming of responsive materials has mainly used stimuli responsive polymers such as PNIPAM but these silica polypeptide composite particles can undergo similar changes by switching the polypeptide conformation. Preliminary jamming studies of the polypeptide composite particles, using fluorescence photobleaching recovery, can be conducted to determine how responsive polymers effect the jamming phase transition of soft colloidal materials.

[9] Heng Chi, Georgia Institute of Technology.

Title: Simulating Soft Materials under Extremely Large deformation: A Mimetic-informed Approach
Authors: Heng Chi, Lourenco Beirao da Veiga, Glaucio H. Paulino

Abstract
We present a computational framework to study hierarchical soft materials under extremely large deformations on polygonal discretizations. Based on mimetic methods, we introduce a novel mixed Virtual Element Method (VEM) framework for finite elasticity. The framework features a nonlinear stabilization scheme, which evolves with deformation; and a local mathematical displacement space, which can effectively handle any element shape, including concave elements or ones with non-planar faces. We verify convergence and accuracy of the proposed mixed virtual elements by means of examples using unique element shapes inspired by Escher (the Dutch artist famous for his impossible constructions). We present a physically-based application of those elements to investigate the nonlinear elastic response of filled elastomers and demonstrate the capability of the VEM-based framework in handling extremely large deformations, which are typical of soft material systems.

[10] Bryan VanSanders, University of Michigan.

Title: Strain Fields in Repulsive Colloidal Crystals
Authors: Bryan VanSanders[1], Julia Dshemuchadse[2], Sharon C. Glotzer[1,2,3]

Affiliation: [1]Department of Materials Science and Engineering, University of Michigan, Ann Arbor, MI 48109; [2]Department of Chemical Engineering, University of Michigan, Ann Arbor, MI 48109; [3]Biointerfaces Institute, University of Michigan, Ann Arbor, MI 48109

Abstract
Crystalline defects can be approximated as linear combinations of local motifs (strains) under the framework of linear elasticity theory. This approach has been widely employed in the metallurgical community; here we show that the elastic strain field approximation is a useful tool in colloidal crystalline systems as well. This work explores the behavior of elastic moduli and strain fields around dislocations within simulated colloidal crystals interacting through a family of repulsive potentials with varying steepness. For steeper potentials, it is found that free energies of deformation are more dominated by entropy, tension-compression asymmetry near dislocation core increases, and the strain range of linear elastic applicability shrinks. We show that pressure is a key parameter for expanding the window of linear elastic applicability for very steep potentials. Using these insights, we show under what conditions linear

elasticity theory can be used as a predicative tool in exploring defect-defect interactions in colloidal crystals.

[11] Yueyi Sun, Georgia Institute of Technology.

Title: understanding collective biophysical behavior of platelets in blood clotting
Authors: Yueyi Sun, David R. Myers, Wilbur a. Lam, Alexeev Alexander

Abstract
The body's natural ability to achieve hemostasis can lead to a life threatening conditions such as, excessive bleeding, stroke or heart attack. Understanding the underlying physics behind the clotting process plays an important role in developing treatment of these disorders. Since clotting is a highly complex multi scale mechanism developing a fully atomistic model is currently not possible. We develop a mesoscale model based on dissipative particle dynamics (DPD) to gain fundamental understanding of the underlying principles controlling the clotting process. In our study, we examine the influence of fibrin and platelet properties on clotting process. Through our model analysis, we discover the importance of heterogeneity of platelets within the clotting process.

[12] Daniel Blatman, Laboratory for Neutron Scattering and Imaging, Paul Scherrer Institute, Switzerland.

Title: Generation of toroidal seeds for heterogeneous nucleation studies of colloids
Authors: Daniel Blatman[1,2], Ya-Wen Chang[2,3], Alexandros Fragkopoulos[2], Perry Ellis[2], Urs Gasser[1] and Alberto Fernandez-Nieves[2]

Affiliations: [1]Laboratory for Neutron Scattering and Imaging, Paul Scherrer Institute, Villigen, Switzerland; [2]Soft Condensed Matter Laboratory, School of Physics, Georgia Institute of Technology, Atlanta, Georgia 30332-0430, USA; [3]Texas Tech University, Department of Chemical Engineering, Lubbock, TX 79409−3121, USA

Abstract
The current work is about the generation of toroidal seeds for heterogeneous nucleation and crystal growth experiments of model colloidal systems on curved surfaces. The torus, being positively curved on the outside and negatively curved on the inside, has a rich geometry and is an interesting object to study. Due to surface tension toroidal droplets will break and shrink to a sphere unless there is an opposing force that stabilizes them. This can be done in a yield stress material. Using a 3D printing process, toroidal droplets of various sizes can be made. After a polymerization process these toroidal seeds can be used for nucleation and crystal growth experiments of colloids using confocal microscopy.

[13] Dali Huang, Texas A&M University.

Title: Magnetically driven functionalized nanoplatelets Pickering emulsion for removal of oil contaminants from water under different environment conditions
Authors: Dali Huang, Minxiang Zeng, Lecheng Zhang, Arun Sabapathy, Janet Sajan, Zhengdong Cheng
(Materials Science & Engineering, Texas A&M University
Artie McFerrin Department of Chemical Engineering, Texas A&M University)

Abstract
There is an immense need for efficient cleanup and recovery of industrial grade oil today. Incidents like the BP rig explosion in Gulf of Mexico in 2010 and Sanchi tanker collision in East China Sea in 2018 have caused huge oil spill and tremendous harm to the environment. The purpose of our research is to develop an effective and inexpensive method to absorb crude oil from oil-water mixtures. Functional magnetic nanoplatelets can be designed as Pickering emulsion surfactant for targeting removal oil contaminants from seawater. Small oil droplets will be stabilized by two-dimensional Pickering emulsifier and can be easily controlled to move by the external magnetic field. The advantage of this approach to extract oil droplets from mixture is that oil droplets can move as designed direction and conveniently be reclaimed

for use. This magnetic driven approach can be considered as an eco-friendly and promising technology for oil water separation.

[14] Andrea Welsh, Georgia Institute of Technology.

Title: Pattern Formation of Brine Shrimp Aggregation
Authors: Andrea J. Welsh, Michael Barnhill, Krishma Singal, Flavio H. Fenton

Abstract
We will discuss the three-dimensional patterns that can be observed by the swarming of brine shrimp, specifically the Great Salt Lake strain of Artemia franciscana, at high concentration. These patterns can be easily observed with simple tabletop experiments; however, the causes of these patterns are unknown. We experimentally test the effects on certain physical parameters such as concentration, temperature, salinity, luminosity, and the relationship of extended-area to depth on the phase separation that produces these patterns. We then develop a model for the shrimps' behavior which will also yield the same sort of patterns. We hope to model the basic length and times scales of the patterns, the patterns selected, the stability of those patterns, and the transitions that occur between patterns.

[15] Barkan Sidar, Montana State University.

Title: Engineering Human Gut Tissues in the Lab
Author: Barkan Sidar; Co-Author / PI: James N. Wilking

Abstract
Human organoids are three-dimensional, millimeter-scale human tissues that replicate much of the structure and function of naturally formed organs. These tissues have a variety of potential applications in biotechnology, including drug formulation testing, regenerative medicine and microbiome research. Despite their potential applications, knowledge of how growth, material transport and mechanical properties influence organoid structure is lacking. The main goal of my research is to understand and optimize the structure of gastrointestinal organoids to improve their viability and reliability as model systems. To achieve this, I use a combination of time-lapse microscopy, image analysis and modeling to develop an understanding of organoid growth and development. Knowledge gained from this work may provide insight into water transport mechanisms across the epithelial tissue, which are poorly understood.

[16] Shashank Markande, Georgia Institute of Technology.

Title: The QTZ-QZD Family of Chiral Triply-Periodic Minimal Surfaces
Authors: Shashank G. Markande[1], Gerd E. Schr¨oder Turk[2], Vanessa Robins[3], Elisabetta A. Matsumoto[1]

Abstract
Cubic phases, which often feature triply-periodic minimal surfaces and their constant mean curvature variants, frequently self-assemble in diblock copolymers, lyotropic liquid crystals, micellar solutions and lipid membranes. These striking, intricate structures are responsible for much of the vivid structural coloration seen in butterfly wing scales and in the shells of beetles. Although some beetles use chiral cholesteric liquid crystals to create circular dichroism, most cubic phases are achiral and do not yield such optical responses. Here, we describe the QTZ-QZD family of surfaces with tunable chiral pitch. We devise an algorithm to generate the QTZ-QZD surface as a function of the chiral pitch, within a suitable range.

[17] Michael Tennenbaum, Georgia Institute of Technology.

Title: Non-linear mechanical properties of fire ant aggregations
Authors: Michael Tennenbaum, Alberto Fernandez-Nieves

Abstract
Fire ant aggregations are inherently active materials. Each ant converts its own chemical energy into motion, and it is the overall motion of all individual ants that contributes to the bulk material properties of

the aggregation. However, the activity level in fire ant aggregations is not constant in time. This lets us measure the material properties of this active material at different activity levels. Here we investigate the non-linear mechanical properties of fire ant aggregations using large amplitude oscillatory shear rheology at varying activity levels and volume fractions. For each oscillatory experiment, we generate Lissajous curves and calculate common non-linear moduli used to characterize the non-linear behavior. Our data suggest that strain stiffening correlates with activity.

[18] Skanda Vivek, Georgia Institute of Technology.

Title: Emergent Collective Risks when Connected Vehicles are Hacked
Authors: Skanda Vivek, David Yanni, Jesse Silverberg, Peter Yunker

Abstract
Internet-connected vehicles have the potential to transform transportation, prevent accidents, reduce congestion, and even improve in-car entertainment. Over forty million connected vehicles are on the road today, with hundreds of millions more expected by 2023. However, the benefits of connectivity come with risks: connected cars are vulnerable to malicious remote hacks. Due to the lack of empirical evidence as well as the computational complexities involved in modeling entire city traffic in the event of a large-scale hack, the magnitude of disruption post large-scale hack is unknown. Here, we develop a novel approach to rapidly simulate, quantify, and possibly mitigate city-wide risks of gridlock post-hack. We find that a surprisingly few number of hacked vehicles cause standstill traffic. We derive a model-independent analytic expression purely based on geometry, to assess the probability of worst-case gridlock, and use this to assess the risks of gridlock post-hack in Manhattan. We find that less than 8,000 hacked vehicles cause significant disruption, and 25% of the city loses access to essential services such as hospitals, police stations, and fire stations. To put this number into context, in 2015, on average 900,000 vehicles entered Manhattan per day, and we estimate a maximum density of around 300,000 vehicles in Manhattan at a time. Our findings suggest only a small fraction of vehicles need to be hacked to cause city-wide gridlock. As a proof-of-concept, we show how network redundancy based solutions can reduce collective risks

[19] Xiaolei Ma, Emory University.

Title: Universal scaling of polygonal crack patterns in dried particulate suspensions
Authors: Xiaolei Ma, Justin C. Burton

Abstract
Cracks induced by drying are prevalent phenomena encountered in nature. In dried polygonal cracks, it is well-known that the characteristic area of the polygons monotonically increases with the material thickness. However, existing theories considering the mechanical, statistical, and hydrodynamical properties of cracking usually lead to contradictory results on this dependence. Here we experimentally investigate this dependence by drying particulate suspensions of cornstarch and CaCO$_3$ particles through varying the film thickness, boundary adhesion, packing fraction, and solvent, and found that the characteristic area of the polygonal cracks, A_p, and film thickness, h, obey a universal power law, $A_p=\alpha h^{4/3}$, with prefactor α depending on the modulus of the film and the adhesion to the surface. This power law is surprisingly consistent with a simple argument of the balance between stress and surface energy for crack formation. Particularly in cornstarch, hierarchical cracks are observed during drying, in which large-scale polygons form at the initial stage of drying due to the water-loss induced stress, whereas small-scale polygons form at a later stage due to the deswelling of the hygroscopic particles. Additionally in thick films of cornstarch-water suspensions, the area of the small-scale polygonal cracks is limited by the diffusion of water vapor during the deswelling of the particles, leading to the formation of the boundary between ``wet'' and ``dry'' particles, and the effective film thickness for small-scale polygonal cracks.

[20] Arben Kalziqi, Georgia Institute of Technology.

Title: Immotile Active Matter: Activity from Death and Reproduction
Authors: Arben Kalziqi, David Yanni, Jacob Thomas, Siu Lung Ng, Skanda Vivek, Brian K. Hammer, and Peter J. Yunker

Abstract
Unlike equilibrium atomic solids, biofilms—soft solids composed of bacterial cells—do not experience significant thermal fluctuations at the constituent level. However, living cells stochastically reproduce and die, provoking a mechanical response. We investigate the mechanical consequences of cellular death and reproduction by measuring surface-height fluctuations of biofilms containing two mutually antagonistic strains of *Vibrio cholerae* that kill one another on contact via the type VI secretion system. While studies of active matter typically focus on activity via constituent mobility, here, activity is mediated by reproduction and death events in otherwise immobilized cells. Biofilm surface topography is measured in the nearly homeostatic limit via white light interferometry. Although biofilms are far from equilibrium systems, measured surface-height fluctuation spectra resemble the spectra of thermal permeable membranes but with an activity-mediated effective temperature, as predicted by *Risler et al.* (PRL 2015). By comparing the activity of killer strains of *V. cholerae* with that of genetically modified strains that cannot kill each other and validating with individual-based simulations, we demonstrate that extracted effective temperatures increase with the amount of death and reproduction and that death and reproduction can fluidize biofilms. Together, these observations demonstrate the unique physical consequences of activity mediated by death and reproduction events.

[21] Shlomi Cohen, Georgia Institute of Technology.

Title: Hyaluronan mediates cell migration speed by regulating adhesion strength
Authors: S. Cohen, P. Kotowska, P. Chang, R. Keate, D. Zhou, A. Garcia, S. Nie, J.E. Curtis

Abstract
The hyaluronan-rich glycocalyx is a dynamic polymeric structure, made of microns-long hyaluronan chains anchored to the cell surface and stretched by large, highly charged bottlebrush proteoglycans. On polarized migrating cells, which have strong adhesions at the front as opposed to weak adhesions in the back, studies show that hyaluronan is distributed asymmetrically with little at the front and much in the back. While hyaluronan is mostly considered to promote cell migration, consistent with the asymmetric distribution, some studies report the opposite. To resolve the disagreement, we use the hydrodynamic assay to study how changes in the interfacial hyaluronan influence cell adhesion strength; and track sparsely-seeded single migrating cells to extract migration features. Our quantitative data suggest that hyaluronan, together with focal adhesions at the cell-substratum interface, can play a role in cell adhesion regulation by two mechanisms: physical repulsion forces by compressed hyaluronan at the interface, and hyaluronan-CD44 biochemical signaling. No matter the adhesion mechanism, our data further suggest that changes in hyaluronan levels at the interface mediate migration speed by regulating the adhesion strength. We suggest a model to conclude the previous contradicted reports, where hyaluronan is an independent regulator of cell adhesion, in addition to the well-studied focal adhesions and surface density of extracellular matrix proteins. Our model predicts that at high extracellular matrix density hyaluronan promotes migration speed, and the opposite for low density.

[22] Thomas Day, Georgia Institute of Technology.

Title: The Role of Physics in the Early Evolution of Multicellularity
Authors: Shane Jacobeen, Elyes C. Graba, Colin G. Brandys, T. Cooper Day, William C. Ratcliff, and Peter J. Yunker

Abstract
The evolutionary transition from single- to multi-celled organisms transformed life on earth by setting the stage for higher orders of organismal complexity. Though this critical transition occurred independently at least 25 times, many aspects of the factors that influence the evolution of nascent multicellularity remain

poorly understood. Recent work has revealed that nascent multicellular 'snowflake' yeast clusters evolve large size by modifying their cellular geometry. Further, geometrically-imposed physical constraints appear to guide evolutionary trajectory of snowflake yeast. Here, we consider the role of environment on the evolutionary fitness landscape of multicellular snowflake yeast by evolving separate populations under various environmental conditions. Using a combination of competition experiments and confocal microscopy to measure relative finesses, we find that a harsh physical environment impedes the evolution of large size. By elucidating the effect of environment on nascent multicellularity, our work aims to provide insight into the conditions favorable for the evolution of complex life.

[23] Zhibo Yuan, Georgia Institute of Technology.

Title: Synergistic Effect of High Temperature Blade Coating and Dielectric Layer Processing for High Performance *n*-Channel Organic Field Effect Transistors
Authors: Zhibo Yuan, Elsa Reichmanis

Abstract
Recently, *n*-channel organic semiconductors with high electron mobilities have drawn significant attention as counterparts to *p*-channel alternatives. In order to enhance device performances, chemicals such as chlorosilane and its derivatives can efficiently remove surface traps, they often leave low energy surfaces that negatively impact film formation processes. In order to investigate the synergistic effects of high temperature and shear force coupled with low energy surfaces, octadecyltrichlorosilane (OTS), phenyltrichlorosilane (PTS) and hexamethyldisilazane (HMDS) were used to treat the dielectric surface. We discovered that the proposed high temperature blade coating method promotes nanofiber network formation on OTS surfaces as confirmed by atomic force microscopy (AFM) results. Charge carrier mobilities for OFETs fabricated using PNDI2Tz and blade coating at elevated temperatures increased by a factor of 6, up to 0.1 $cm^2V^{-1}s^{-1}$ compared to pristine devices. Such charge carrier transport characteristics confirm the significant potential for bithiazole in the development of electron transport semiconducting materials exhibiting promising properties for organic photovoltaic (OPV) and OFET applications.

[24] Cornelia Rosu, Georgia Institute of Technology.

Title: Liquid crystal-directed organization of polypeptide-coated silica dome-shaped particles into hierarchical structures
Authors: Cornelia Rosu, Shane Jacobeen, Peter Yunker, Elsa Reichmanis and Paul S. Russo

Protein-caged materials like viruses interact daily with and within living bodies. Rational design of synthetic platforms may help understand the nature of these interactions. Polypeptide-coated particles resemble viruses; therefore they are called disease-inspired materials. In this study, poly(γ-stearyl-L-glutamate) (PSLG)-coated silica dome-shaped particles were suspended in a PSLG cholesteric liquid crystal matrix at various concentrations. In all samples investigated PSLG particles disturbed the local ordering of the director field evidenced by the disappearance of the bulk cholesteric fingerprint. After one month in low-concentrated samples PSLG particles were seen to follow a pattern specific to native PSLG cholesteric liquid crystal matrix. In medium- and high-concentrated samples at the liquid crystal-glass vial interface, PSLG particles adopted a hexagonal and lamellar packing which was thick. The bulk PSLG matrix was able to regain its native fingerprint appearance.

[25] Tyler Shendruk, Rockefeller University.

Title: Exopolymer dynamics driven by flagellated microorganisms
Authors: Tyler N Shendruk, Andrew K Balin, Andreas Zöttl and Julia Yeomans

Abstract
Microbial flagellates typically inhabit complex suspensions of polymeric biomaterials which can impact the swimming speed, filter-feeding, and biofilm generation. There is a need to better understand how the dynamics of exopolymers near beating flagella impacts transport. Our Stokesian dynamics simulations

provide insight on the hydrodynamic interactions of a model monoflagellate on suspended polymers. As a stationary rotating helix pumps fluid along its long axis, polymers migrate radially inwards while being elongated. We observe that the actuation of the helix tends to increase the probability of finding polymeric material within its pervaded volume, implying that a dilute suspension of polymers tend to become locally concentrated in and around the flagellum rather than depleted.

[26] Jonas Cuadrado, Georgia Institute of Technology.

Title: Internal mass sergregation in PNIPAM micogrels
Authors: Jonas Cuadrado, Boyang Zhou, Changwoo Do, Alberto Fernandez-Nieves

Abstract
Colloidal hydrogels swell and deswell depending on the environmental conditions. These size changes imply changes in the single-particle properties, including their internal structure, which can result in non-trivial morphologies. Here, we use PNIPAM-AAc ultra-low crosslinked particles at different temperature and charge, together with light and neutron scattering, to find that the particles are not homogenous. Instead, they are remarkably heterogeneous. We interpret the results in terms of phase separation using the Borue and Erukhimovich theory

[27] Perry Ellis, Georgia Institute of Technology.

Title: Defects in an active nematic confined to a toroid
Authors: Perry Ellis, Alberto Fernandez-Nieves

Abstract
Active materials are driven far from the ground state by the motion of their constituent particles, thereby making them inherently non-equilibrium materials. For an active nematic, this results in a continuous creation and annihilation of ±1/2 topological defect pairs. When we confine an active nematic to the surface of a toroid, we find that the topological charge, the defect density, and the defect orientation couple to the curvature of the underlying surface.

[28] Volodymyr Korolovych, Georgia Institute of Technology.

Title: Cellulose Nanocrystals with Different Morphologies and Chiral Properties
Authors: Volodymyr F. Korolovych [a], Vladyslav Cherpak [a], Dhriti Nepal [b], Amy Ng [b], Anise Grant [a], Rui Xiong [a], Timothy J. Bunning [b], Vladimir V. Tsukruk [a]

[a] School of Materials Science and Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332, USA
[b] Air Force Research Laboratory, Materials and Manufacturing Directorate, Wright Patterson Air Force Base, Ohio 45433, USA

Abstract
The study reports the morphology and optical properties of a variety of cellulose nanocrystals (CNC) obtained from various natural sources with different dimensions and composition of individual nanocrystals and their selective light reflectance in the solid state. A library of CNCs with different dimensions, sulfate contents, and crystallite sizes was prepared from five distinct sources representing traditional choice ranging from soft and hard wood pulps to microcrystalline cellulose under identical hydrolysis conditions. High-resolution atomic force microscopy, scanning electron microscopy, scanning transmission electron microscopy, and X-ray diffraction confirmed that all CNCs have a well-defined rod-like morphology with different aspect ratios and axi-asymmetric diamond-shape cross-sections. Varying the cellulose sources while utilizing constant processing conditions resulted in wide variability of the CNC dimensions with lengths from 120 to 210 nm, aspect ratios from 30 to 70, heights from 2.9 to 3.6 nm and widths from 6 to 11 nm. Specifically, the CNCs from microcrystalline sources have large cross-sectional dimensions and produce straight CNC bundles, but CNCs from various wood pulps have small cross-sections and facilitate twisted local bundles of a few individual nanocrystals. Chemical composition and

surface potentials were found to be less critical to the resulting chiral characteristics and structural colors while the CNCs with high aspect ratios form chiral films with large pitch values and thus longer wavelengths of selective reflection. Such flexible chiral CNC materials with controlled optical signature can be further considered for development of advanced materials for colorimetric sensors, tunable and active photonic materials, optical coatings, chiral inks and 3D printed photonic structures.

[29] Adrien Saremi, Georgia Institute of Technology.

Title: Controlling the Softness of Metamaterials: Corner Modes via Topology
Authors: Adrien Saremi, Zeb Rocklin

Abstract
The structure of a vast range of soft materials determines how they deform under external forces. In particular, systems that are soft because they are at the point of mechanical stability have been shown to have topological properties that lead to robust new deformations. Here we extend this topological softness to otherwise rigid periodic mechanical structures. A higher order topological invariant creates, directs and protects modes on their boundaries. We introduce a model system consisting of rigid quadrilaterals joined at their corners. This bulk structure generates a topological linear deformation mode exponentially localized in one corner, as investigated numerically and via experimental prototype. Unlike previous topological mechanical systems, these structures select a single desired mode, which controls variable stiffness and mechanical amplification that can be incorporated into soft materials at any scale.

[30] David Yanni, Georgia Institute of Technology.

Title*:* Life in the Coffee-Ring
Authors: David Yanni, Arben Kalziqi, Skanda Vivek, Jacob Thomas, Siu Lung Ng, Matt Repasky, William Ratcliffe, Brian Hammer, Peter Yunker

Abstract
Microbial life is abundant, present in virtually any drop of water, from ocean spray, to dew drops, to raindrops, to sneeze aerosols. When a drop lands on a solid surface and evaporates, it leaves microbes in a new environment wherein they interact, compete, and form biofilms - densely packed, surface-attached, polymicrobial communities. Evolutionary outcomes thus depend on the results of competitions within biofilms, which, in turn, depend not only on competitor identities and relative frequencies, but also on their spatial arrangement. Despite recent work on the importance of spatial structure in mature biofilms, it remains unclear how and to what extent the initial spatial structure, set during the earliest stages of biofilm formation, shapes the outcome of competition and community structure. This is in large part due to the lack of a unified picture of how initial conditions emerge in disparate environments, especially for sessile polymicrobial communities. However, drying drops almost always exhibit the so-called coffee-ring effect; when a drop dries, it leaves a ring-shaped deposit of anything suspended within it, including cells. This ubiquitous phenomenon thus likely plays a role determining the initial conditions in nearly all air-solid biofilms founded by microbes in a droplet. Here we show, using biofilm experiments and cellular automaton simulations, how the coffee-ring effect can determine community structure, affect phenotypic expression, and decide competitions during the early stages of biofilm development. Further, we show that this effect is quite robust across multiple substrates and for diverse taxa. Our results demonstrate the importance of initial conditions in the context of spatial microbial competition within sessile communities, and highlight the role of the coffee-ring effect in determining which competitive strategies will be advantageous. Given the robustness of the coffee-ring effect, and that a drop of rain, freshwater, or a sneeze aerosol can contain millions of microbes, we expect that this scenario plays out frequently in both ecological and artificial settings, and further affects countless laboratory experiments.

[31] María L. Jiménez

Title: Experimental analysis of the electro-orientation of gold nanorods
Authors: María L. Jiménez, Paloma Arenas-Guerrero, Silvia Ahualli, Angel V. Delgado
Affiliation: Department of Applied Physics, School of Sciences, University of Granada, Avda. Fuentenueva sn, 18071-Granada,

Abstract
In this work, we show the electric birefringence spectra of gold nanorods coated by a CTAB layer. The electric field induces a dipole around the particles which is not aligned with the applied field, and hence, there is an electric torque that produces a certain degree of orientation. The sample becomes birefringent, and this optical response can be analyzed to get information about the polarization mechanisms. We observe that the CTAB soft layer determine the birefringence at low frequencies. An interpretation in light of soft particles polarization model is provided: ions in this layer produce a large dipole responsible for the response of this system. The results are contrasted with electrophoresis data, providing information about the charge of the interface between particle and solution.

[32] Arturo Moncho

Title: Sorption and Spatial Distribution of Protein Globules in Charged Hydrogel Particles
Authors: Irene Adroher-Benítez, Arturo Moncho-Jordá́, and Joachim Dzubiella

Abstract
In this work we have theoretically studied the uptake of a non-uniformly charged biomolecule suitable for representing a globular protein or a drug by a charged hydrogel carrier in the presence of a 1:1 electrolyte. On the basis of the analysis of a physical interaction Hamiltonian including monopolar, dipolar, and Born (self-energy) contributions derived from linear electrostatic theory of the unperturbed homogeneous hydrogel, we have identified five different sorption states of the system, from complete repulsion of the molecule to its full sorption deep inside the hydrogel, passing through metastable and stable surface adsorption states. The results are summarized in state diagrams that also explore the effects of varying the electrolyte concentration, the sign of the net electric charge of the biomolecule, and the role of including excluded-volume (steric) or hydrophobic biomolecule−hydrogel interactions. We show that the dipole moment of the biomolecule is a key parameter controlling the spatial distribution of the globules. In particular, biomolecules with a large dipole moment tend to be adsorbed at the external surface of the hydrogel, even if like-charged, whereas uniformly charged biomolecules tend to partition toward the internal core of an oppositely charged hydrogel. Hydrophobic attraction shifts the states toward the internal sorption of the biomolecule, whereas steric repulsion promotes surface adsorption for oppositely charged biomolecules or for the total exclusion of likely charged ones. Our results establish a guideline for the spatial partitioning of proteins and drugs in hydrogel carriers, tunable by the hydrogel charge, pH, and salt concentration.

[33] Minxiang Zeng, Texas A&M University.

Title: Superhydrophobic Porous Sponges coated with Functional Graphene Quantum Dots for Oil-water Separation Application under Different Environmental Conditions
Authors: Dali Huang, Minxiang Zeng, Arun Sabapathy, Janet Sajan, Zhengdong Cheng
Materials Science & Engineering, Texas A&M University; Artie McFerrin Department of Chemical Engineering, Texas A&M University

In today’s society, there is an immense need for efficient cleanup and recovery of crude oil. Oil spills in seawater have resulted in the billions of dollars loss and tremendous pollution to the environment. Demulsifiers in industry for separating oil from water might be detrimental to oceanic environments and small oil droplets are difficult to remove. Our proposed solution is to fabricate a superhydrophobic melamine sponge to separate oil from seawater. The reusable sponge is coated with hydrophobic graphene quantum dots and fluorinated-silane, making it possible for the sponge to absorb small oil droplets and prevent the passage of water under different environmental conditions. Our findings suggest

that the functionalized superhydrophobic sponges are eco-friendly and cost efficient with good potential for widespread application in the oil spill treatment area.

[34] Pavel Aprelev, Clemson University.

Title: Surprising solutions to a fundamental problem: materials science of wound healing in insects
Authors: Pavel Aprelev, Bonni McKinney, Bryan Wiggers, Dr. Peter Adler, Dr. Konstantin Kornev

Abstract
Blood in insects (hemolymph) plays a vital role in processes that range in scale from macroscopic – such as primary wound healing – to microscopic – such as flowing through vessels to deliver nutrients – to nanoscopic – such as fending off bacteria and viruses. From a rheological perspective, hemolymph is a suspension of adherent and non-adherent micron-sized hemocytes suspended in plasma. During wound healing, these hemocytes interact with each other and proteins from the plasma to stop bleeding in less than a minute! Due to the small amount and the fragility of the primary clot, the material properties of this process have never been studied before. We have developed various experimental techniques to study the rheological as well as surface properties of hemolymph during wound healing, when the sample volume is measured in microliters. We probe the nano-rheology of hemolymph by suspending magnetic nanorods in a droplet of hemolymph and tracking their rotation in response to a rotating magnetic field. We probe extensional rheology of hemolymph by observing decay dynamics of filaments produced between two rapidly spread apart surfaces. We combine rheological, structural, and surface behavior data to put forward a hypothesis on how insects are able to stop bleeding in so quickly.

[35] William Savoie, Georgia Institute of Technology.

Title: Clog control in confined excavating collectives
Authors: J. Aguilar, D. Monaenkova, V. Linevich, W. Savoie, B. Dutta, H. Kuan, M. Betterton, M. A. D. Goodisman, D. I. Goldman

Abstract
Systems consisting of living and non-living ensembles of self-propelled entities can spontaneously form clusters, clogs and jams. However, such structure formation can be detrimental to collective task completion in crowded collectives; therefore development of robust strategies of clog control are essential. Based on biological and robophysical experiments, and supported by computational and theoretical models, we find that substrate excavation performance can be robustly optimized within the constraints of narrow tunnels by individual idleness and retreating. Tools from the study of dense particulate ensembles elucidate how these seemingly counterproductive strategies lead to optimum traffic flow density: idleness reduces the frequency of flow-stopping clogs, and selective retreating reduces clog dissolution time for the rare clogs that still occur. Our results point to strategies by which active materials and swarms can become task-capable without sophisticated sensing, planning and global control of the collective.

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Title: Collisional diffraction during serpentine self-propulsion
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Abstract
Natural and artificial self-propelled systems must manage environmental interactions during movement. Such interactions, which we refer to as active collisions, are fundamentally different from momentum-conserving interactions of classical physics, largely because the internal driving can lead to persistent contact with heterogeneities. We study the effects of active collisions on a laterally-undulating sensory-deprived robophysical snake. Interactions with a single row of evenly-spaced posts (spacing d) produce distributions reminiscent of far-field diffraction patterns: as d decreases, distinct secondary peaks emerge

as large deflections become more likely. We find the nature of individual collisions do not change depend on d; instead, the likelihood of individual collisions to occur is altered. As d decreases, collisions near the leading edges of the posts become more probable, and we find that these interactions are associated with larger deflections.