2007 APS March Meeting

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Monday, March 5, 2007 8:00AM - 11:12AM –
Session A29 DFD: Focus Session: Colloids I Colorado Convention Center 303

8:00AM A29.00001 How confinement modifies the colloidal glass transition[1] ERIC R. WEEKS, Emory University — We study concentrated colloidal suspensions, a model system which has a glass transition. These are suspensions of small solid particles in a liquid, and exhibit glassy behavior when the particle concentration is high; the particles are roughly analogous to individual molecules in a traditional glass. We view the motion of these colloidal particles in three dimensions by using an optical confocal microscope. This allows us to directly study the microscopic behavior responsible for the macroscopic viscosity divergence of glasses. In particular, we study how confinement changes the particle dynamics. We confine a colloidal suspension between two parallel walls, and find that in thin sample chambers the particle motion is greatly slowed. This suggests that confinement causes the onset of the glass transition to happen "sooner," at particle concentrations which are not normally glassy.

[1]Supported by the National Science Foundation under Grant No. DMR-0239109.

8:36AM A29.00002 Periodic Stresses and Shear Thickening in an Attractive Colloidal Gel[1] , CHINEDUM OSUJI, DAVID WEITZ, Applied Physics, Harvard University — We report on the observation of periodic stresses in a colloidal gel at rest and under minute shear deformation. Dilute suspensions of carbon black colloidal particles in hydrocarbon oil with an attractive Van der Waals interaction are found to shear thicken in two distinct regimes. The first, low shear rate regime is ascribed to network elongation and the high shear regime to hydrodynamic clustering, akin to that observed in concentrated hard sphere systems. Due to the attractive interaction between particles, the shear thickened state persists long after cessation of flow and in the high shear rate regime gives rise to high modulus, compacted networks. These gels display residual stresses and exhibit a peculiar time dependent aging in which the normal force exerted by the stationary gel as well as the shear modulus display low frequency long lived oscillations. Simple tensile deformation of the gel results in comparatively higher frequency periodic normal forces. We propose a simple mechanism to account for the observed data.

[1]The authors gratefully acknowledge the Infineum Corporation for financial support of this work

8:48AM A29.00003 Plastic restructuring in compressed colloidal glasses[1] , DANIEL BLAIR, DAVID WEITZ, Harvard University — We report the observation of localized plastic restructuring in compressed colloidal glasses. By placing a expanding bulk hydrogel in contact with the colloidal glass, we can drive the system above the glass transition volume fraction, $\phi = 0.58 \rightarrow 0.64$. We measure the local strain tensor using three dimensional confocal microscopy and particle tracking techniques. The increase in volume fraction exhibits a smooth exponential increase. However, local irreversible transformations exhibit strong fluctuations that are correlated to the local free volume. We will elucidate the mechanisms for these localized relaxation events, and make comparisons to recent models of sheared amorphous solids.

[1]Funding from the NSF under grant DMR-0602684

9:00AM A29.00004 Ideal Glass Transitions, Barrier Hopping and Dynamic Heterogeniety in Suspensions of Nonspherical Colloids , G. YATSENKO, K.S. SCHWEIZER, University of Illinois, Urbana, IL 61801 — The slow translational dynamics and nongaussian fluctuation effects of glassy isotropic fluids composed of nonspherical objects is studied based on a nonlinear stochastic Langevin equation of motion that includes activated barrier hopping. Suspensions of homonuclear diatomic and linear triatomic shaped colloids of variable bond length have been studied. The ideal glass transition boundary (crossover to activated dynamics) is predicted to be a nonmonotonic function of particle aspect ratio and surprisingly occurs at a nearly unique value of the dimensionless compressibility. The magnitude and volume fraction dependences of the entropic barrier, localization length and shear moduli for different aspect ratio systems collapse well onto master curves based on a reduced volume fraction variable that quantifies the distance from the ideal glass transition. Calculations for long polyatomic rods have also been performed. The ideal glass boundary decreases with aspect ratio slower than the nematic phase transition boundary. Solution of the nonlinear Langevin equation via Brownian trajectory simulation have also been performed. Results for the mean square displacement, decoupling of relaxation and diffusion, nongaussian parameter and other measures of dynamic heterogeneity have been determined for different colloidal shapes.

9:12AM A29.00005 Experimental Measurement of Freezing Kinetics in Two-Dimensional Colloidal Crystals , J.R. SAVAGE, A.D. DINSMORE, Umass, Amherst — We study the freezing kinetics of two-dimensional colloidal crystals formed by a short-range attractive potential. We use aqueous suspensions of micron-sized latex spheres mixed with surfactant micelles, which create a depletion attraction among the spheres. The depletion attraction between the spheres and the coverslip enables us to create a two-dimensional system. Upon uniformly heating or cooling the sample, the micelles grow or shrink and the depletion attraction changes in magnitude. Optical microscopy is used to track the motions of thousands of colloidal spheres in the process of freezing or melting . By varying the density (area fractions of 17-34%) and the amount of supercooling, we can measure the dynamics of nucleation and growth of crystallites. A two-stage nucleation process can be seen in samples with density of 30% in which a meta-stable liquid droplet is first formed; then the crystallite is nucleated from within. At higher and lower densities the crystals nucleate in the typical fashion with large 6-fold orientational symmetry at small cluster size. We will present results on the evolution of the orientational order of crystallites and their degree of crystallinity as a function of both time and cluster size. We will also compare and contrast these density dependent freezing results to earlier work done on the melting process. This work is supported by the NSF-DMR 0605839.

9:24AM A29.00006 Particle dynamics near the re-entrant glass transition , ANDRZEJ LATKA, Saint Joseph's University, AHMED ALSAYED, YILONG HAN, ARJUN YODH, University of Pennsylvania, PIOTR HABDAS, Saint Joseph's University — Colloidal suspensions are a model system for studying the glass transition. At the volume fraction $\phi g \approx 0.58$ a hard sphere colloidal glass is formed. The formation of a hard sphere glass is attributed to the caging effect, in which the particles form cages around each other that restrict their movement. Introducing an attractive depletion force between the particles causes the hard sphere glass to melt and the system becomes a liquid. Through further increase of the attractive force an attractive glass is formed. Our system is a suspension of nearly hard-sphere colloidal particles and nonadsorbing linear polymer which induces a depletion attraction between the particles. Using microscopy techniques, we study how the dynamics of the particles change as the attractive potential is increased and attractive glass is approached. In particular, we examine the mean square displacement and frequency of particle jumps over a range of attraction strengths.

9:36AM A29.00007 Translation-rotation coupling in dense colloidal suspensions , MINSU KIM, Dept. of Physics, University of Illinois at Urbana and Champaign, STEPHEN ANTHONY, Dept. of Chemistry, University of Illinois at Urbana and Champaign, STEVE GRANICK, Dept. of Material Science and Engineering, University of Illinois at Urbana and Champaign — Single-particle tracking has been used to contrast translational and rotational diffusion in colloidal suspensions. Not enough is known from prior study about the rotation of colloids, owing perhaps to the paucity of suitable measurements techniques, but this is now remedied by using Modulated Optical Nanoparticles(MOONs), which are fabricated by capping one hemisphere with a thin layer of reflective metal. Density of the suspensions is varied and both translational and rotational mean squared displacement are quantified.

9:48AM A29.00008 Single liposome tracking in dense suspensions of stabilized liposomes , YAN YU, Dept of Materials Science and Engineering, Univ of Illinois at Urbana-Champaign, STEPHEN ANTHONY, Dept of Chemistry, Univ of Illinois at Urbana-Champaign, LIANGFANG ZHANG, Dept of Chemical Engineering, Univ of Illinois at Urbana-Champaign, ANGELO CACCIUTO, STEVE GRANICK, Dept of Materials Science and Engineering, Univ of Illinois at Urbana-Champaign — Methods developed to stabilize phospholipid vesicles against fusion, up to volume fraction around 80%, enable one to perform single-particle tracking on these soft, flexible, hollow objects. Stabilization is accomplished by studding the outer leaflet with charged nm-sized particles. Image analysis of time trajectories, obtained using epifluorescence imaging, was performed at sub-pixel resolution. This talk will emphasize aspects of curiously heterogeneous dynamics and also quantification of "cage" size in this system. Taken together, this system of charged, polydisperse, flexible objects displays rich dynamics that contrasts acutely with known behavior for hard-sphere dense particle systems.

10:00AM A29.00009 Yield stress of stearically stabilized colloids , SURESH AHUJA, Xerox Corporation, TERRY BLUHM — The bulk property, yield stress has been modeled by Larson in the past for spherical colloidal particles with dependence on volume fraction of solids particle diameter and interaction potential (sum of van der Waals potential and electrostatic potential. In our organic pigment dispersions polymer stabilized followed Herschel-Bulkley equation with yield stress which was non-linearly dependent on pigment surface area measured by BET. Stability of dispersions changed with time in terms of particle size and yield stress as well as on the type of deformation, shear applied to the dispersion. The results of yield stress are compared with models in terms of interaction potential, particle size and zeta potential..

10:12AM A29.00010 Janus Colloids Assemble into Cluster Shapes , LIANG HONG, ANGELO CACCIUTO, ERIK LUIJTEN, STEVE GRANICK, University of Illinois at Urbana-Champaign — We explore the assembly of two types of micron-sized, spherical Janus particles: those with opposite electric charge on both hemispheres ("bipolar") and those hydrophobic on one hemisphere and hydrophilic on the other ("amphiphilic"). Bipolar particles form clusters, not strings, as the particle diameter exceeds the electrostatic screening length. The cluster shapes are analyzed by combined epifluorescence microscopy and Monte Carlo computer simulations with excellent agreement, indicating that the particles assemble in aqueous suspension to form equilibrated aggregates. The simulations show that charge asymmetry of individual bipolar particles is preserved in the clusters. The assembly of amphiphilic particles presents analogies to the self-assembly of molecular surfactants, forming monolayers at the air-water interface and micelles in the aqueous suspension. By tuning the salt concentration, different phases of micelle can be imaged in real space. Computer simulations confirm the geometries of these micelles and reveal possible formation mechanisms.

10:24AM A29.00011 Wetting layer dynamics in colloid polymer mixtures by evanescent wave dynamic light scattering , BENOIT LOPPINET, PANGIOTIS VOUDOURIS, GIORGOS PETEKIDIS, IESL-FORTH Heraklion Greece — Evanescent wave obtained at the total internal reflection can be used as the incident beam of a dynamic light scattering experiment where its short penetration depth allow to selectively probe fluctuations close to a hard wall. Colloid concentration fluctuation in gas-liquid phase separated colloid-polymer mixtures obtained with PMMA hard spheres (R=120nm) and polystyrene polymer in index match cis/trans decalin were investigated in the vicinity of a vertical hard wall with in particular the dense colloidal layer wetting the hard wall in the top (gas) phase. There, the q-dependent collective dynamics reveal a liquid like behaviour similar to the one observed in the bottom phase dynamics, both marginally slower than the dynamics measured in the bottom (liquid) phase bulk and very different from the dilute like dynamics observed in the bulk top phase. Results are discussed in terms of hydrodynamic interactions.

10:36AM A29.00012 Gravitational collapse of depletion gels , JUAN JOSE LIETOR-SANTOS, ALBERTO FERNANDEZ-NIEVES, CHANJOONG KIM, PETER J. LU, DAVID A. WEITZ, Division of Engineering and Applied Science. Harvard University — We study how colloidal gels collapse under the presence of a gravitational stress. We do so macroscopically, monitoring the time dependence of the creaming or sedimentation front, and microscopically, using confocal microscopy. Our system consists of fluorescently labeled spheres that are index matched to the surrounding solvent. Temperature allows fine control of the density mismatch, further enabling fine tuning of the gravitational stress. Addition of non-adsorbing polymer induces an attraction whose range and strength can also be tuned. We will present results pertaining macroscopic studies for different particle volume fractions and interaction energies and preliminary microscopic results aiming to locally describe the structure collapse.

10:48AM A29.00013 Depletion Interaction: Effect of Depletant's Non-ideality , DZINA KLESHCHANOK, REMCO TUINIER, PETER R. LANG, Forschungszentrum Jülich, SOFT MATTER TEAM — Depletion interaction is one of the central issues of colloidal stability; it arises between colloidal bodies suspended in a solution of non-adsorbing polymers, micelles, spheres, rods etc. Recently depletion of ideal non-ionic monodisperse polymers, monodisperse hard spheres and rods was extensively studied using various theoretical methods [1]. These cases enable a detailed theoretical analysis and serve as a model for other more complicated systems. However, in many experimental cases the depletants deviate from the requirements of the theories, for example, one has to deal with polydisperse, charged or (partly) adsorbing depletants. Another problem can arise when it is not possible to use the Derjaguin approximation to compute the depletion potential (e.g. the size of depletant is comparable with the size of colloids). All these effects can lead to the crucial deviations from the idealizing theories. We experimentally studied depletion interaction induced by non-ideal depletants between a charged colloidal sphere and a charged solid wall using Total Internal Reflection Microscopy (TIRM). Here we discuss the influence on the depletion potential due to the polymer size polydispersity (dextran), polymer's adsorption (polyethylene oxide (PEO)) and the colloid/ depletant's size ratio (fd-viruses). .1. Tuinier, R. et al., *Adv. Colloid Interface Sci* **2003,** 103, 1.

11:00AM A29.00014 Direct observation of dynamical heterogeneity near the colloidal gel transition , MARIA KILFOIL, YONGXIANG GAO, McGill University — We use confocal microscopy to probe the microscopic dynamics near the colloidal gel transition where the dynamics shows spatial heterogeneity. We are able to separate fast and slow particles independently from self part of van Hove density-density correlation function. The distinct part of van Hove correlation function shows clearly a signature of dynamical heterogeneity and the behavior is dominated by the fast particles. We further observe intermittent dynamics for these particles: the motion is not continuous. This provides the first microscopic picture of intermittent dynamics in colloidal gels.

Monday, March 5, 2007 8:00AM - 11:00AM –

Session A30 DFD: Self-Assembly of Particles, Droplets, and Amphiphilic Molecules Colorado Convention Center 304

8:00AM A30.00001 ABSTRACT WITHDRAWN –

8:12AM A30.00002 ABSTRACT WITHDRAWN –

8:24AM A30.00003 Solution Phase Behavior of Gold Nanoparticles in Colloidal Solution , HAO YAN, AMITABHA CHAKRABARTI, CHRISTOPHER SORENSEN, Kansas State University — Gold nanoparticles in colloidal solution can aggregate to form gold nanocrystal superlattices. To explore and understand the solution phase behavior of nanoparticles, the gold nanoparticles ligated with dodecanthiol in a mixture of 4-tert-butyltoluene and butanone were studied by UV-vis spectroscopy, static light scattering and dynamic light scattering. The results showed that there is a reversible dissolution-aggregation process. The phase diagram was obtained by measuring the size of the nanoparticles with dynamic light scattering and the scattered light intensity. The UV-vis spectroscopy also proved the existence of a phase transition.

8:36AM A30.00004 Self Assembly of Colloidal Particles at Small N , GUANGNAN MENG, Harvard University, ZHENGDONG CHENG, Texas A&M University, MICHAEL BRENNER, Harvard University, VINOTHAN MANOHARAN, Havard University, DEPARTMENT OF PHYSICS, HARVARD UNIVERSITY COLLABORATION, DEPARTMENT OF CHEMICAL ENGINEERING, TEXAS A&M UNIVERSITY COLLABORATION — We confine the dilute colloidal suspension inside emulsion droplets and study the structures of the aggregated clusters at small particle number ($N \approx 10$) in order to understand the governing rules of equilibrium self-assembly. The aggregation process is controlled by the short-range weak depletion attraction between particles, and the structural and dynamic properties of self-assembled colloidal clusters are monitored via optical microscopy. We compare the experimental results with the theory and simulations, which probe how the number of local minima increases with number of particles. Our system may be a good model system for understanding generic features of glass and gel transitions.

8:48AM A30.00005 Self-Organization of Bouncing Oil Drops: Two-Dimensional Lattices and Spinning Clusters[1] , SUZANNE LIEBER, MELISSA HENDERSHOTT, APICHART PATTANAPORKRATANA, JOSEPH MACLENNAN, University of Colorado — Multiple oil drops bouncing on the surface of a vertically vibrating bath of the same oil exhibit self-organization behavior in two dimensions. S. Protière et al. [J. Phys.: Condens. Matter **17**, S3529 (2005)] recently reported that such drops arrange themselves in triangular lattices, with a lattice spacing dependent on the driving frequency of the bath. We describe here the morphology and dynamic behavior of stable assemblies of large bouncing oil drops, for which we find that not only the spacing but the lattice structure itself changes with frequency, with variants of both square and hexagonal structures being observed. Large "rafts" of drops form soft triangular lattices with faceted boundaries. Small clusters of drops are unstable to coherent, collective spinning under certain driving conditions, manifesting spontaneous rotational symmetry breaking.

[1]This work was supported by NSF MRSEC Grant No. DMR-0213918 and by NASA Grant NAG-NNC04GA50G.

9:00AM A30.00006 Self-assembly of helical tubules using a single-tailed surfactant. , HEE-YOUNG LEE, SRINIVASA RAGHAVAN, University of Maryland — Hollow micro or nanotubules are an unusual type of self-assembled structure that can be formed in aqueous solution. Such structures could be useful in a variety of applications such as in controlled drug delivery and in electroactive composites. However, these structures are typically formed only by some unusual lipids (i.e., two-tailed amphiphiles) or certain peptides. Here we present a very simple and economical process to make stable tubules by using a single-tailed diacetylenic surfactant in conjunction with an alcohol. The formation of tubules as a function of solution composition and temperature are systematically investigated in this study. The tubules are visualized by optical microscopy, while their detailed structure is seen under TEM. We find that the tubules have helical markings, which is remarkable considering that the precursor molecules are achiral. Our results provide further evidence that molecular chirality is not essential to forming tubules; presumably, tubules can form from achiral molecules by a chiral symmetry-breaking process.

9:12AM A30.00007 Aggregation Properties and Liquid Crystal Phase of a Dye Based on Naphthalenetetracarboxylic Acid , MICHELLE TOMASIK, PETER COLLINGS, Swarthmore College — R003 is a dye produced for thin film optical components by Optiva, Inc.[1] made from the sulfonation of the dibenzimidazole derivative of naphthalenetetracarboxylic acid. Its molecular structure is very different from the aggregating food dye previously investigated in our laboratory[2] and R003 forms a liquid crystal phase at significantly lower concentrations. We have performed polarizing microscopy, absorption spectroscopy, and x-ray diffraction experiments in order to determine the phase diagram and aggregate structure. In addition, we have included both translational and orientational entropy in the theoretical analysis of the aggregation process, and have used a more realistic lineshape in analyzing the absorption data. Our results indicate that the "bond energy" for molecules in an aggregate is even larger than for the previously studied dye and that the aggregate structure has a cross-sectional area equal to two or three molecular areas rather than one.

[1]Lazarev, P., N. Ovchinnikova, M. Paukshto, SID Int. Symp. Digest of Tech. Papers, San Jose, California, June XXXII, 571 (2001).
[2]V. R. Horowitz, L. A. Janowitz, A. L. Modic, P. A. Heiney, and P. J. Collings, Phys. Rev. E 72, 041710 (2005).

9:24AM A30.00008 Effects of Multivalent Salts and Polyamines on Lyotropic Chromonic Liquid Crystals[1] , L. TORTORA, H.S. PARK, Liquid Crystal Institute and Chemical Physics Interdisciplinary Program, Kent State university, D. FINOTELLO, Department of Physics, Kent State University, O.D. LAVRENTOVICH, Liquid Crystal Institute and Chemical Physics Interdisciplinary Program, Kent State university — Multivalent salts and polyamines cause significant structural and phase changes in lyotropic chromonic liquid crystals (LCLCs) such as water solutions of sunset yellow (also known as Edicol), disodium chromoglycate, and blue 27. Using polarizing microscopy, rheoscopy, retardance mapping, and preliminary small-angle neutron scattering data, we demonstrate that multivalent additives cause significant shifts of phase boundaries in the temperature-concentration coordinates, formation of aggregate bundles, as well as induce phase separation of a homogeneous nematic phase into hexagonal columnar and isotropic phases. The multivalent phenomena are discussed within the framework of the strong coupling model of polyelectrolyte interactions and hydration effects.

[1]Work was partially supported by AFOSR MURI grant FA9550-06-1-0337, NSF grant DMR 0504516, and OBR B-7844 grant.

9:36AM A30.00009 Nanoparticle organization in surfactant mesophases , GURUSWAMY KUMARASWAMY, National Chemical Laboratory, Pune, India, KAMENDRA SHARMA, NCL, Pune, India — Dispersing colloidal particles in surfactant liquid crystalline phases leads to the formation of materials with ordered microstructures. The influence of the liquid crystalline medium leads to organization of the colloidal particles, and the driving force for self-assembly scales with the size of the colloids. Micron-sized colloids organize into linear arrays in liquid crystals, while nanoparticles can be confined in surfactant liquid crystal structures. We investigate the dispersion of silica nanoparticles with sizes of 7, 11 and 23nm in hexagonal mesophases of aqueous solutions of nonionic surfactants. The surfactant mesophase is preserved after dispersion of these particles, and the particles organize to form lamellar structures. We will discuss the implications of our results for the synthesis of novel materials.

9:48AM A30.00010 Self-assembly of ionic detergents: a simulation study of sodium dodecyl sulfate micellization , MARIA SAMMALKORPI, Department of Mechanical and Aerospace Engineering, Princeton University, Princeton, New Jersey 08544, USA, MIKKO KARTTUNEN, Department of Applied Mathematics, University of Western Ontario, Middlesex College, 1151 Richmond St. North, London (ON), Canada, MIKKO HAATAJA, Department of Mechanical and Aerospace Engineering, Princeton University, Princeton, New Jersey 08544, USA — Detergents, amphiphilic molecules used to separate and dissolve molecular aggregates and also as cleaning agents, consist of a polar head group and one or more hydrophobic tails. Above a critical concentration, they self-aggregate in an aqueous solution to form micelles. While industrially extremely important, surprisingly little is known about molecular details of the self-assembly of detergents. Here we extend our previous work of modeling and model construction of charged soft-matter systems [1] by a description of an anionic detergent, sodium dodecyl sulfate (SDS) [2]. We present the results of large-scale Molecular Dynamics simulations of the formation dynamics and structure of SDS micelles. We demonstrate that temperature affects micelle morphologies through the packing and discuss the effect of SDS concentration on the micellization.

[1] M. Patra et al., Biophys. J. 84, 3636 (2003); A. A. Gurtovenko et al., J. Phys. Chem. B 109, 21126 (2005); A. A. Gurtovenko et al., Biophys. J. 86, 3461 (2004).

[2] The SDS parameters are available at www.softsimu.org.

10:00AM A30.00011 Evidence for condensed lipid/cholesterol complexes in lipid membranes. , MARIA K. RATAJCZAK, SHELLI L. FREY, EVA CHI, CANAY EGE, THEODORE L. STECK, University of Chicago, YVONNE LANGE, Rush University, JAREK MAJEWSKI, Los Alamos National Laboratory, KRISTIAN KJAER, Riso National Laboratory, KA YEE C. LEE, University of Chicago — Certain binary mixtures of phospholipids and cholesterol exhibit phase diagrams with two immiscibility regions with a sharp cusp in between. The cusp has been suggested to represent the stoichiometry of phospholipid/cholesterol complexes, and cholesterol is thought to exist in two states: a bound, low activity state, and an unbound, high activity state. To better understand the interaction between phospholipids and cholesterol, we have studied the effect of a possible displacing agent, hexadecanol, on the behavior of the binary mixture. Our cholesterol desorption assays indicate that hexadecanol can displace cholesterol from its association with phospholipids, thereby activating it. Phospholipid/cholesterol/hexadecanol systems in which a fraction of cholesterol is replaced by the alcohol have phase diagrams that mimic those of binary systems with the same apparent molar stoichiometry. X-ray data show a broad Bragg peak in these binary systems, indicating that order in these complexes extend over only several molecular dimensions.

10:12AM A30.00012 Concentration-curvature coupling in endocytosis, , SARAH NOWAK, Dept of Biomathematics, UCLA, Los Angeles, CA 90095-1766, TOM CHOU, Dept. of Biomathematics and Dept. of Mathematics, UCLA, Los Angeles, CA 90095-1766 — The wrapping of symmetric particles by lipid bilayers depends on the membrane bending rigidity and the adhesion between the membrane and the particle. We consider the additional effects of a membrane composed of a binary lipid mixture. The different lipid components induce different spontaneous curvatures, which mediates the wrapping process through an induced phase separation near the particle-membrane contact region. We find that mixtures always enhance the wrapping. Asymptotic results are also found for the membrane shape in the limit of strong and weak spontaneous curvature-lipid concentration coupling.

10:24AM A30.00013 Entropy-driven ordering in soft matter[1] , YU-QIANG MA, Nanjing University — In this talk, we discuss the entropic effects on the structural organization on the basis of the following three examples of our recent works: 1) phase behavior in thin film of confined colloid-polymer mixtures, 2) the organization in inclusion-membrane complexes, and 3) lateral organization in supported membrane on a geometrically patterned substrate. The result will be helpful for understanding the physical mechanism of structural organization and controlling novel structures of soft materials under the guidence of entropy driven ordering.

[1]This work was supported by the National Natural Science Foundation of China, No. 10334020, No. 10021001, No.20490220.

10:36AM A30.00014 Soft quasicrystals - Why are they stable?[1] , RON LIFSHITZ, HAIM DIAMANT, Tel Aviv University — In the last two years we have witnessed the exciting experimental discovery of soft matter with nontrivial quasiperiodic long-range order—a new form of matter termed a *soft quasicrystal*. Two groups have independently discovered such order in soft matter: The first in a system of dendrimer liquid crystals [1]; and the second in a system of ABC star-shaped polymers [2]. These newly discovered soft quasicrystals not only provide exciting platforms for the fundamental study of both quasicrystals and of soft matter, but also hold the promise for new applications based on self-assembled nanomaterials with unique physical properties that take advantage of the quasiperiodicity, such as complete and isotropic photonic band-gap materials [3]. Here we provide a concise review of the emerging field of soft quasicrystals [4], and invoke an old theory [5] suggesting that the existence of two natural length-scales, along with 3-body interactions, may constitute the underlying source of their stability.

[1] Zeng *et al.*, Nature **428** (2004) 157.

[2] Takano *et al.*, J. Polym. Sci. Polym. Phys.**43** (2005) 2427.

[3] Zoorob *et al.*, Nature **404** (2000) 740.

[4] Lifshitz & Diamant, preprint (cond-mat/0611115).

[5] Lifshitz & Petrich, Phys. Rev. Lett. **79** (1997) 1261.

[1]Supported by the Israel Science Foundation, grant number 684/06.

10:48AM A30.00015 Directing self-assembly by tailoring pair potentials of soft shoulder systems , ZACH SMITH, PAUL BEALE, NOEL CLARK, MATT GLASER, Dept. of Physics, University of Colorado, Boulder — Monodisperse spheres interacting via 'hard core/soft shoulder' (HCSS) pair potentials (e.g., hard spheres with an additional repulsive step interaction) exhibit extremely rich phase behavior, including a diverse array of two- and three-dimensional liquid crystal phases and a wide variety of complex crystal structures [M. A. Glaser et al., cond-mat/0609570], including relatively open crystal structures such as the 2D honeycomb lattice [E. A. Jagla, J. Chem. Phys. 110, 451 (1999)]. The complex phase behavior of this class of systems derives from competition between an underlying 'soft shoulder' clustering instability [W. Klein et al., Physica A 205, 738 (1994)] and excluded volume constraints. We show that it is possible to derive soft shoulder potentials to promote self-assembly of specific target structures using only geometrical information. We have applied this approach to the self-assembly of a stable 3D diamond lattice in systems of particles with isotropic pair interactions, demonstrating that anisotropic, directional bonding is not a necessary requirement for formation of the diamond lattice. This approach, which exploits soft shoulder clustering behavior, is a powerful tool for the directed design of a variety of unusual and complex self-assembled systems. Work supported by NSF MRSEC Grant DMR-0213918 and GAANN Fellowship P200A030179.

Monday, March 5, 2007 11:15AM - 2:15PM –

Session B29 DFD: Dense Granular Flows and Jamming Colorado Convention Center 303

11:15AM B29.00001 Affine and Non-Affine motion in a Granular Couette Experiment[1] , BRIAN UTTER, James Madison University, ROBERT BEHRINGER, Duke University

— We characterize local motion of grains in a 2D granular Couette shear. In steady state, grains exhibit a shear band, where the grains are dilated near the shearing surface, $r = 0$. The mean velocity is in the tangential direction, and decays somwhat faster than exponentially. We characterize the local motion by tracking small clusters of particles. The overall motion of the cluster can be described in terms of a smooth affine part, and a non-affine part that is not captured by the smooth deformation. We determine the measure of non-affine motion, D^2_{min} of Falk and Langer. This quantity shows characteristic distributions that initially grow roughly as power laws, but are then cut off exponentially. Distributions of non-affine displacements for individual particles are roughly guassians. The width of these distributions, the widths of the distributions for D^2_{min} and previously measured diffusivities show essentially identical variation with local shear rate. We understand the formation of the shear band from an initially homogeneous packing in terms of outwardly directed diffusion next to the shearing surface. In the steady state, there is a balance between inward diffusion from a density gradient, and ourward diffusion driven by the shearing.

[1]Work supported by NASA grant NNC04GB08G and NSF grant DMS0555431

11:27AM B29.00002 Nonlinear elastic stress response in granular materials[1] , BRIAN TIGHE, Universiteit Leiden, JOSHUA SOCOLAR, Duke University

— We study the response of two-dimensional granular materials to a local boundary force, for which classical elasticity predicts identical stress states in the cases of isotropic and hexagonally anisotropic materials. We probe the differences in these two cases by including corrections from the full nonlinear elasticity theory. Additionally, we model the effect of discrete microstructure by taking the magnitude of multipole stress response terms, which are induced in the nonlinear system, as material parameters. By so incorporating both anisotropy and microstructure, reasonable fits are obtained for experimental stress response profiles in hexagonal packings of photoelastic grains, while either correction alone is insufficient.

[1]This work was supported by NSF Grant No. DMR-0137119.

11:39AM B29.00003 Upward penetration through a granular medium , D. COSTANTINO, Penn State; Physics Department, T.J. SHEIDEMANTEL, M.B. STONE, J. COLE, C. CONGER, K. KLEIN, M. LOHR, W. MCCONVILLE, Z. MODIG, P. SCHIFFER

— We measure the force needed to push a flat plunger upwards through a granular medium. The plunger begins flush with the base of the grains' container, and we focus upon the force necessary to initiate motion. The data show that this break-out force increases monotonically with plunger diameter and pile height as expected. In contrast to previous measurements of the force needed for vertical penetration from above and of the horizontal drag force, this break-out force has a strong dependence on the diameter of beads making up the pile. The nature of this bead size dependence can be altered by using different methods to form the grain pile. Implications for the relevant force chain network will be discussed. Research supported by NASA grant NAG3-2384 and the NSF REU program.

11:51AM B29.00004 Sound and Force Propagation in Granular Materials , CLIFFORD E. CHAFIN, KAREN E. DANIELS, Physics Dept., North Carolina State University

— A characteristic of granular materials under stress is a highly nonuniform distribution of forces. These localized force chains are prominent of 2-D packings of photoelastic particles, but their role in sound propagation is unclear. We mechanically excite 100 μs square wave pulses and periodic waveforms through such packings. We report optical measurements of changes in the force chain network using a high speed camera, and simultaneous acoustic measurements from biaxial accelerometers of similar size and mass to the photoelastic particles. These measurements provide amplitude and speed (time of flight and group velocities) of the response both on and off the force chain network.

12:03PM B29.00005 Testing the equal-probability assumption of jammed particle packings , GUO-JIE GAO, JERZY BLAWZDZIEWICZ, COREY O'HERN, Yale University

— The Edwards' entropy formalism provides a statistical mechanical framework for describing dense granular systems. In addition, experiments on vibrated granular columns and numerical simulations of quasi-static shear flow of dense granular systems have provided evidence that the Edwards' theory may accurately describe certain aspects of these systems. However, a fundamental assumption of the Edwards' description—that all mechanically stable (MS) granular packings at a given packing fraction are equally likely—has not been explicitly tested in dense granular systems. We investigate this assumption by generating all mechanically stable hard disk packings in small systems using a protocol in which we successively compress or decompress the system followed by energy minimization. We then apply quasi-static shear flow at fixed pressure to these MS packings to study the frequency with which MS packings occur during the shear flow. We find that the MS packings do not occur with equal probability during the shear flow, in fact, there is a significant reduction in the number of accessible MS packings at large shear strain. Thus, the Edwards' entropy formalism should be re-examined in light of our findings.

12:15PM B29.00006 Experimental study of the compaction dynamics for 2D granular pile of spherical and cylindrical grains , GEOFFROY LUMAY, NICOLAS VANDEWALLE, FRANCOIS LUDEWIG, University of Liege

— We present an experimental study of the compaction dynamics for two-dimensional granular systems. The compaction of a pile of spherical grains and of a pile of cylindrical grains have been studied. Compaction dynamics is measured at three different scales : the macroscopic scale through the normalized packing fraction, the mesoscopic scale through the normalized fraction of ideally ordered domains in the system, and the microscopic scale through the grain mobility. Moreover, the ideally ordered domains are found to obey a growth process dominated by the displacement of domain boundaries. A global picture of compaction dynamics relevant at each scale is proposed.

12:27PM B29.00007 Packing and segregation in thermally cycled granular materials , KE CHEN, JOHN DRASKOVIC, Physics Dept. of Penn State Univ., JULIA COLE, Aerospace engineering Dept. of Penn State Univ., ANDREW HARRIS, CASEY CONGER, MATTHEW LOHR, Physics Dept. of Penn State Univ., KIT KLEIN, Dept. of Computer Engineering of Penn State Univ., THOMAS SCHEIDEMANTEL, PETER SCHIFFER, Physics Dept. of Penn State Univ.

— We have studied the change of packing fraction of granular materials and the displacement of an intruder in a granular pile under thermal cycling. We find that the packing fraction of granular materials increases with thermal cycling, i.e., heating the sample and returning it to ambient temperature. This effect appears to be related to the difference in thermal expansion between the container and the grains, and it increases monotonically with increasing cycle temperature. The packing fraction further increases under multiple thermal cycles and the increasing packing fraction can be fit to a double exponential decay toward the random close packing. We also find that spherical intruders in granular piles can move downward with thermal cycling, and that this effect depends on the relative density of the grains and the intruder as well as the relative thermal expansion of the grains and the container. This research was supported by the NASA through grant NAG3-2384 and the NSF REU program through grant DMR 0305238.

12:39PM B29.00008 Experimental Characterization of the Jamming Transition in a Granular Material[1]

TRUSHANT MAJMUDAR[2], MIT, ROBERT BEHRINGER, Duke University — We describe experiments to test recent predictions for the jamming transition in disordered solids. Here, our system is a 2D granular material consisting of photoelastic disks. By observing these particles through crossed circular polarizers, it is possible to a) accurately determine particle contacts, b) via an appropriate computational procedure, calculate the vector contact forces between particles, and c) from the contact forces compute the Cauchy stress. Simulations (e.g. by O'Hern et al., Donev et al.) for frictionless particles predict a discontinuous increase in the contact number, Z at the jamming transition, given by a critical packing fraction, ϕ_c. Above jamming, Z should then increase as a power law in $\phi - \phi_c$ with an exponent of 0.5 to 0.6. The pressure, P is also predicted to grow as a power law. Additionally, Senkes and Chakraborty have predicted the behavior of P and Z using a meanfield entropy-based description. Our experiments support all of these predictions. There is a rapid increase in Z at ϕ_c, and power law increase of Z and P above the transition. There is also reasonable agreement between the data and the predictions of Senkens and Chakraborty.

[1]Work supported by NSF grant DMS0555431
[2]Work done at Duke University

12:51PM B29.00009 Stress, strain rate, and free volume in dense granular flow

CHRIS RYCROFT, KEN KAMRIN, MARTIN BAZANT, Massachusetts Institute of Technology — There have been many attempts to describe dense granular flow with continuum models, but a complete theory is still lacking. Often, these models make assumptions about microscopic quantities (such as shear stress, strain rate, and local density) and here we present Discrete Element Method (DEM) simulations to directly measure these in a variety of different non-homogeneous granular flows. Motivated by previous work, we compute these quantities on a mesoscopic length scale of several particle diameters, and examine both spatial distributions, and correlations between the variables. We investigate the validity of the commonly-used Mohr-Coulomb incipient yield hypothesis, which states that the ratio of shear stress to normal stress should be everywhere constant in a flowing granular material. Our results also show some striking correlations between strain rate and local density, which suggest a phase transition between static and flowing granular materials.

1:03PM B29.00010 The force network in emulsions and the role of external stress[1]

JING ZHOU, TIM PRISK, University of Massachusetts Amherst, SU LONG, University of South Carolina, HABIB SKAFF, University of Massachusetts Amherst, QIAN WANG, University of South Carolina, TODD EMRICK, ANTHONY D. DINSMORE, University of Massachusetts Amherst — Direct imaging of emulsion droplets labeled with fluorescent nanoparticles using confocal microscopy is a valuable experimental tool for studying granular materials in three dimensions. By measuring individual droplet-droplet contacts inside the frictionless emulsion piles, we visualize the force network and calculate the orientations, positions, and magnitudes of forces and their statistical distributions. We find that large forces are more likely to align parallel to each other, leading to long-range, chain-like correlations of magnitude and direction of contact force. Furthermore, we investigate how the force network evolves with time and how it changes under various external stresses. We also measure the contact force at the bottom of emulsion piles and compare to previous surface measurements and the measurement inside the bulk. This work may shed light on the aging and macroscopic viscoelasticity of granular systems.

[1]Support from NSF DMR-0605839

1:15PM B29.00011 The packing and compaction dynamics of granular polymers

LING-NAN ZOU, XIANG CHENG, HEINRICH JAEGER, SIDNEY NAGEL, The James Franck Insitute, The University of Chicago — While the packing of hard spheres has been the subject of intense research, the packing of objects with reduced symmetries is far less well-studied, both experimentally and theoretically. Here, we report an experimental study on the packing of a granular polymer analogue — chains of hollow, spherical brass beads, 1.9 mm in diameter, ranging in length from a 1 to 42 700 beads per chain. In particular, we systematically measure the density ρ of the bead-chain pack as a function of the number of beads per chain M (*i.e.* the molecular weight of the granular polymer). The density decreases from the random close packed density $\rho_{RCP} \approx 0.64$ for single beads to an asymptotic density $\rho_\infty \approx 0.39$ in the limit of very long chains; the form of the density fall-off is rather slow, the effect is noticeable even when M is much larger than the chain persistence length. In terms of dynamics, the compaction of bead-chain packs appears to obey the same logarithmic relaxation form found in the compaction of single bead packs [1], but with a puzzling, M-dependent sensitivity to initial conditions. We shall discuss these results in the context of, and attempt to make connections to, the packing of single hard spheres on one hand and the physics of polymer melts on the other. [1] J. B. Knight *et al.*, Phys. Rev. E **51**, 3957 - 3963 (1995).

1:27PM B29.00012 The Stochastic Flow Rule and Rate Sensitivity in Dense Granular Flows.

KEN KAMRIN, CHRIS H. RYCROFT, MARTIN Z. BAZANT, MIT — The Stochastic Flow Rule (SFR) is a constitutive law which, when used with limit-state Mohr-Coulomb plasticity for stresses, gives predictions for the mean velocity field in quasi-2D dense granular flows. It is based on a simple microscopic flow mechanism, where "spots" of free volume perform random walks along slip-lines, biased by stress imbalances upon local fluidization. The SFR has recently been shown to predict dense granular flows in diverse geometries— e.g. draining silos, annular Couette cells, and plate-dragging experiments— without the use of fitting parameters. However, a significant rheological change occurs in certain geometries— e.g. inclined plane flow and gravity-free horizontal shear flow— where the packing fraction is nearly uniform and a distinct stress/strain-rate relationship arises. In this talk, we review the SFR and propose a simple explanation of when and why rate sensitivity occurs, depending on the slip-line geometry. We also postulate how rate-dependent terms may be combined with the SFR to create a more universal theory of dense flows.

1:39PM B29.00013 The Dynamics of Sandpile Model and Its Application to Earthquakes

YUNFAN GONG, Weill Med. College of Cornell Univ. — Just from the simple yet widespread power laws, it seems unlikely to differentiate self-organized criticality (SOC) from other mechanisms proposed for power-law relationships. Here we report SOC phenomenon in a sandpile model driven by chaos. We characterize SOC by analyzing times series from the system. Surprisingly, we find that the microscopic dynamics of the complex sandpile system can be best approximated by a very simple one-order autoregressive (AR) model. Meanwhile, the AR model can well reproduce almost all power-law behaviors of the sandpile model, suggesting a similar dynamics between the complex sandpile system and the simple one-order AR model. Next, real earthquake time series including Harvard catalog and source time functions (STFs) are analyzed along the same lines. The one-order linear dynamics fitted from the STFs is in excellent agreement with that of the sandpile model, whereas the optimal two-order dynamics fitted from the STFs is a false mode and should be rejected. Our results support that earthquakes can be considered as a SOC process and suggest that they may be governed by sandpile models with high order (≥ 2) dynamics.

1:51PM B29.00014 Smoothing a Rock by Chipping[1]

SIDNEY REDNER, PAUL KRAPIVSKY, Boston University — We investigate an idealized model for the size reduction and smoothing of a polygonal rock due to repeated chipping at corners. Each chip is sufficiently small so that only a single corner and a fraction of its two adjacent sides are cut from the object in a single chipping event. After a large number of chipping events, the shape is not circular, with the distribution of facet lengths and corner angles broadly distributed. In the long-time limit, the shape of the object is not a unique, but rather is characterized by large sample-to-sample fluctuations.

[1]Work supported from NSF grants CHE0532969 (PLK) and DMR0535503 (SR)

2:03PM B29.00015 Comparison of the influence of a strong current and of a spark on the distribution of the resistance of a contact between two grains[1] , STEPHANE DORBOLO, University of Liege, ALEXANDRE MERLEN, University of Toulon, ERIC FALCON, Laboratoir MSC, Paris VII, MATTHIEU CREYSSELS, University of Rennes, BERNARD CASTAING, ENS Lyon, NICOLAS VANDEWALLE, University of Liege — The distribution of the electrical resistance of a contact between two stainless steel beads is a log normal. When a current is injected through a contact, the voltage is not univocally determined. The system exhibits hysteresis. A chain of beads have been used to make some statistic and to determine how a strong current or a electric spark modify the distribution of the resistance. A strong current changes the distribution of resistance into a nearly gaussian distribution. The contacts are soldered by the current. On the other hand, a spark only modifies the highest resistances. The value of the minimum resistance that is modified is determined by the distance between the spark and the bead chains.

[1]SD thanks FNRS for financial support

Monday, March 5, 2007 11:15AM - 2:15PM –
Session B30 DFD: Instabilities and Turbulence Colorado Convention Center 304

11:15AM B30.00001 Lagrangian statistics in two-dimensional turbulence , MICHAEL RIVERA, ROBERT ECKE, Los Alamos National Laboratory — Using data obtained from a stably stratified shallow layer of fluid, we generate Lagrangian trajectories from which a number of statistical quantities can be calculated. Of particular interest are the Lagrangian structure functions of the velocity difference and the acceleration statistics. We find Kolmogorov like scaling in the Lagrangian structure functions (when plotted using ESS) in the direct enstrophy cascade range, and deviations from Kolmogorov in the inverse energy cascade range. This is somewhat surprising because there is a marked lack of intermittency in the inverse energy range. Intermittency is associated with deviations from Kolmogorov scaling in three-dimensional experiments.

11:27AM B30.00002 Pressure Fluctuations in Two-dimensional Turbulence , YONGGUN JUN, Department of Physics of Complex Systems, Weizmann Institute of Science, X.L. WU, Department of Physics, University of Pittsburgh — We investigate pressure fluctuations in two-dimensional (2D) turbulence driven electromagnetically in a freely suspended soap film. The reduced probability distribution function (PDF), $P(p/\sigma_p)$, is found to be universal for different Reynolds numbers and consists of asymmetrical exponential wings, where $\sigma_p \equiv \langle p^2\rangle^{1/2}$ is the standard deviation. The calculated pressure skewness $S_p = \langle p^3\rangle/\sigma_p^3 \simeq -0.5$ is significantly smaller than predictions by simple 2D models (Holzer and Siggia, Phys. Fluids A5, 2525 (1993)) but surprisingly close to 3D calculations using a random velocity field with a Kolmogorov energy spectrum $E(k) \propto k^{-5/3}$. The pressure spectrum $E_{pp}(k)$ scales approximately as $E_{pp}(k) \propto k^{-7/3}$ in the energy inverse-cascade subrange and k^{-5} in the enstrophy cascade subrange. These observations suggest that pressure fluctuations is essentially a large-scale phenomenon and the presence of an enstrophy cascade has no effect on the tails of $P(p/\sigma_p)$.

11:39AM B30.00003 Large-Eddy Simulation (LES) of the NASA Hump Flow Using Dynamic Sub-Grid-Scale (SGS) Model , SUBHADEEP GAN, URMILA GHIA, KIRTI GHIA, University of Cincinnati — LES using dynamic SGS models is employed to investigate turbulent flow over the NASA Hump flow. This has a simple geometry, but, nevertheless, is rich in many complex flow phenomena such as shear layer instability, separation, reattachment, and vortex interactions. The flow is first simulated using the dynamic SGS model (Germano *et al.*, 1991) with freestream Reynolds number of approximately 936,000 and standard atmospheric conditions. Next, LES with an integral-type localization two-parameter dynamic SGS model (Wang and Bergstrom, 2004) is employed. A multi-block structured 3D computational grid is used for the simulation. Mean-velocity contours, turbulent kinetic energy contours, and streamlines will be examined. Detailed comparisons will be made of mean and turbulence statistics such as the pressure coefficient, skin-friction coefficient, Reynolds stress profiles, and wall shear stress, with experimental results. The location of the reattachment behind the hump will be compared with previously published numerical simulations and experimental results. The correlation between the large-scale coherent structures and the SGS events is expected to be predicted more accurately by the integral-type localization two-parameter dynamic SGS model in comparison to eddy viscosity models.

11:51AM B30.00004 Three regularizations as turbulent subgrid models[1] , JONATHAN PIETARILA GRAHAM, NCAR, DARRYL HOLM, Imperial College & LANL, PABLO MININNI, ANNICK POUQUET, NCAR — Geophysical and astrophysical phenomena involve a huge range of scales. The number of degrees of freedom are inconceivable for numerical simulations to achieve, and truncation of the omitted scales removes important physics. Regularization subgrid models for this closure problem have recently emerged. Unlike many Large Eddy Simulations (LES), these models have guarantees on the computability of their solutions, conserve energy, and recover the physical equations as the filter width vanishes. Three regularizations can be viewed as LES with successively more complex subgrid-stress terms: the Clark, Leray, and alpha models. Comparing these, we establish the affects of each term. As each has different small-scale energy spectra this can shed light on the link between small-scale properties of the flows and their intermittent behavior. We find that Leray fails to recover large-scale anisotropy in our flow and the time scale for the development of turbulence. The Clark and alpha models both perform well in these regards but require extra dissipative for adequate computational gains. We also test the helicity of vortex tubes, Beltramization of the flow, and statistical properties for the subgrid models.

[1]NCAR is sponsored by the National Science Foundation.

12:03PM B30.00005 Simultaneous Velocity Discrimination Method of Two-Phase Flows Using Time Resolved Stereo PIV and PTV , P.B. VANDERWERKER, Y. CHEN, M.M. TORREGROSA, F.J. DIEZ, Rutgers University, S. PHOTOS, D. TROOLIN, TSI Inc — Multiphase jets laden with particles appear in many engineering and environmental processes. Typical examples are sprays containing liquid fuel drops in combustion processes, air jets laden with coal particles in a power plant, and the dispersion of harmful substances like soot and pollutants from steady exhaust flows, among others. Studies of particle-laden turbulent flows suggest that particle distribution is not uniform but preferential. In order to understand the mechanism of particle dispersion, time resolved simultaneous 3D velocity measurements of the disperse phase and of the fluid flow were made. Two-phase discrimination algorithms were developed based upon the filtering methodology proposed by Khalitov & Longmire (2002), allowing for complete separation of the two-phases in stereo PIV images. The different filtering methods studied include separation of the two-phases using: (1) particle size discrimination, (2) particle intensity discrimination, (3) particle size and intensity discrimination, and (4) fluorescent particles for one of the two-phases. This methodology also enables time-resolved instantaneous 3D velocity fields using PTV and PIV on the disperse phase and fluid flow phase respectively. These allow visualization of 3D turbulent coherent structure evolution in the fluid as well as the evolution of the dispersed phase.

12:15PM B30.00006 Measurement of entrainment and mixing in oceanic overflows , PHILIPPE ODIER[1], JUN CHEN, MICHAEL RIVERA, ROBERT ECKE, Los Alamos National Laboratory — The mixing and entrainment processes existing in oceanic overflows, e.g., Denmark Strait Overflow (DSO), affect the global thermohaline circulation. Owing to limited spatial resolution in global climate prediction simulations, the small-scale dynamics of oceanic mixing must be properly modeled. We have built a facility (Oceanic Overflow Facility) allowing the study of a gravity current along an inclined plate, flowing into a steady ambient medium. At small values of the Richardson number, the shear dominates the stabilizing effect of the stratification and the flow at the interface of the current becomes unstable, resulting in turbulent mixing. In addition, the level of turbulence is enhanced by an active grid device. Using PIV and PLIF to measure, respectively, the velocity and density fields, we characterize the statistical properties of the mixing. We also study the entrainment of the ambient fluid by the flow. An accurate parametrization of the mixing and entrainment can be a valuable input for ocean circulation models.

[1]Permanent Affiliation: Laboratoire de Physique, ENS Lyon

12:27PM B30.00007 Finite Size Effects in the Quasi-geostrophic Inverse Cascade , COLM CONNAUGHTON, CNLS-LANL — In the standard statistical theory of quasi-geostrophic turbulence forced at intermediate scales, two cascades are produced. Energy flows to large scales and potential enstrophy flows to small scales. The inverse cascade of energy is very similar to that which occurs in purely two-dimensional hydrodynamics. In that case, interesting phenomena occur if the friction between the fluid layer and the substrate is sufficientlyweak to allow the inverse cascade to reach the size of the system. Most striking among these is the spontaneous emergence of very intense coherent vortices which suppress turbulent fluctuations. A similar situation can arise in the quasi-geostrophic inverse cascade if the Ekman damping is weak enough, the scenario which I will describe in this talk. The situation is richer because large scale coherence can be obtained either through the formation of large vortices or through the formation of zonal jets.

12:39PM B30.00008 Measured oscillations of the velocity and temperature fields in turbulent Rayleigh-Bénard convection in a rectangular cell[1] , SHENG-QI ZHOU, CHAO SUN, KE-QING XIA, Dept. of Physics, The Chinese University of Hong Kong — We report experimental measurements of the velocity and temperature oscillations in a rectangular cell. The aspect ratios are $\Gamma_x = 1$ and $\Gamma_y = 1/4$ so that the large scale convective flow is confined in the plane of $\Gamma_x = 1$. From particle image velocimetry (PIV) measurement it is found that the large-scale flow plane aligns along the diagonal plane of the cell. The large scale circulation is found to be oscillatory based on analysis of the autocorrelation functions of the velocity and temperature fields. It is well known that oscillations of velocity and temperature exist in cylindrical cells. The fact that they are now also found in a rectangular cell suggests that the oscillation phenomenon is an intrinsic character of the convective flow rather than the geometric character of convection cell. In the range of Ra from 3.5×10^{10} to 9×10^{11}, it found that the oscillation frequency of temperature $f_T \sim Ra^{0.45}$ and that of the velocity $f_V \sim Ra^{0.51}$, which are close to results from previous measurements made in cylindrical cells.

[1]Work supported by the Hong Kong Research Grants Council Grant 403705.

12:51PM B30.00009 A connexion between turbulence in Rayleigh Taylor flows and turbulence in other buoyant flows , OLIVIER POUJADE, CEA — An increasing number of numerical simulations and experiments describing the turbulent spectrum of Rayleigh-Taylor (RT) mixing layers came to light over the past few years. Results reported in recent studies allow to rule out a turbulence *à la Kolmogorov* as the main mechanism acting on a self similar RT turbulent mixing layer. In this case, the injected power is due to buoyancy motion on a broad range of length scales. We have generalised Lin's spectral equation to buoyant flows and we have shown that this injected power tends to accumulate at large scales so that big whirls can get bigger as the mixing layer thickness increases. Only a small fraction of this power is transferred to small scales through a Kolmogorov cascade and dissipated. This balance between the accumulation of energy at large scales and the buoyancy production can also be applied to Rayleigh-Bénard instabilities. It explains the Bolgiano-Obukov scaling predicted and experimentally observed for these flows.

1:03PM B30.00010 Unsteady Kelvin-Helmholtz instability of an inmiscible interface with a large contrast in viscosity , HARUNORI YOSHIKAWA, JOSE-EDUARDO WESFREID, PMMH-UMR7636 (CNRS-ESPCI-P6-P7) — We studied a stability problem of two-layer oscillatory flows, especially with an interest in the case of a large contrast in viscosity at the interface. Preceding experimental studies showed that static deformations of the interface, often referred to as "frozen waves," happened beyond a threshold. Theoretically, we examined exhaustively the linear stability of the system for any viscosity contrast. What we found are: (i) destabilizing effect by the viscosity contrast and (ii) frequency dependence of the wave length selected by the linearly most instable mode. Instability is provoked by a smaller excitation in the case of large viscosity contrast within a certain band of frequency. The second point shows a deviation from the classical KHI. For high frequencies, the most instable mode has the capillary wave length, while for low frequencies, a longer one. Within an intermediate frequency range, the most instable mode can have a shorter wave length than the capillary one, depending on the viscosity contrast. We also realized a model experiment in a small-frequency range rarely investigated in the preceding studies. The two fluids were chosen so that the contrast in viscosity was very large (10^4 times difference in kinematics viscosity). Interface behavior was determined in detail. Results were in good agreement with our theoretical predictions.

1:15PM B30.00011 Growth of Convective and Absolute Instabilities in Co-flowing Jets , ANDREW UTADA, ALBERTO FERNANDEZ-NIEVES, DAVID WEITZ, Division of Engineering and Applied Science, Harvard University, Cambridge MA 02138, USA — We have shown recently that the dripping-to-jetting transition in co-flowing liquids is controlled by two non-dimensional numbers: the capillary number ($\mathbf{Ca}_{out}$) of the outer liquid and the Weber number of the inner liquid ($\mathbf{We}_{in}$). When jetting is forced by $\mathbf{Ca}_{out}$, the diameter of the jet narrows in the downstream direction and the drop size scaling is well predicted assuming that the Rayleigh-Plateau instability is convected along the jet to cause its break up. However, when jetting is forced by $\mathbf{We}_{in}$, the diameter of the jet widens in the downstream direction and the resultant drop size can not be predicted assuming that the Rayleigh-Plateau instability causes the jet to break up. Instead, we believe these jets break due to absolute instabilities.

1:27PM B30.00012 Lattice Boltzmann Model for Two-Dimensional Flow of Immiscible Fluids between Closely-Spaced Plates , ALEX FORE, ROBERT SEKERKA, MICHAEL WIDOM, Carnegie Mellon University — We formulate a Lattice Boltzmann (LB) model for simulation of two-dimensional flow of nearly-immiscibile fluids between closely spaced parallel plates. We treat displacement of a more viscous fluid by a less viscous fluid, as in a Hele-Shaw cell. The nearly two dimensional flow leads to the well-known Saffman-Taylor instability. We use a binary (A-B) LB model to simulate the problem. We account for the effects of the thin dimension between the plates via a drag force that we obtain by averaging the equations of motion over the thin dimension. We consider the A-B solution to be a regular solution with a strongly repulsive potential and use the effective potential method, consistent with equilibrium thermodynamics, to model non-ideal solutions. To control the viscosity of each phase we use a mixing rule for the relaxation time that depends linearly on mole fraction. We use a gradient energy on the mole fraction to attain control over the interface width and surface tension. We use this model to simulate viscous fluid displacement in a rectangular Hele-Shaw cell. Preliminary results display the Saffman-Taylor instability which we compare with a classical linear stability analysis. We have also observed time development of nonlinear fingering patterns.

1:39PM B30.00013 A Numerical Study of Shock-Bubble Multiple Interaction[1] , LINGLING WU, XIAOLIN LI, SUNY at Stony Brook — This paper studies the numerical solution of shock-bubble multiple interactions through reflecting walls. Front tracking method is applied to track the dynamic motion of the interface and FFT method is used to analyze the enstrophy changes during the process. Our results suggest that the enstrophy is a monotonically increasing function of the Mach number and the bubble radius when the density ratio of the two fluids inside and outside the bubble is fixed. Moreover from light-in/heavy-out to heavy-in/light-out, enstrophy is a monotonic function of the Atwood number. The analysis of these different cases provides a quantitative understanding about the vorticity generation in the turbulent mixing as a result of the Richtmyer-Meshkov instability induced by shock-contact interaction. We have also compared numerical solutions with and without tracking of the contact surface. The comparison shows that the untracked solution suffered substantial loss of enstrophy due to numerical diffusion.

[1]Lingling Wu is supported in part by the Renaissance Technologies Fellowship, Lingling Wu and Xiaolin Li are supported in part by Department of Energy Grant DEFC0201ER25461.

1:51PM B30.00014 Non-Brownian microrheology of a fluid-gel interface , ERIK K. HOBBIE, SHENG LIN-GIBSON, NIST, SATISH KUMAR, University of Minnesota — We use stroboscopic video microscopy to study the stability of a planar fluid-gel interface under simple steady shear flow. External mechanical noise plays a role analogous to temperature, with periodic fluctuations associated with the repeated build-up and release of stress. We relate the high frequency motion of the interface to the rheological properties of the underlying gel, pointing toward potential applications in the area of non-Brownian optical microrheology. At low frequency, the data suggest a breakdown of linear response, which we interpret as the emergence of an instability that is intrinsic to the driven interface.

2:03PM B30.00015 Spin dewetting of wetting and partially wetting fluids , SHOMEEK MUKHOPADHYAY, ROBERT BEHRINGER, Physics Department, Duke University — One of the classical results of fluid dynamics is the free-surface flow of a viscous liquid in a vertically rotating cylinder, where the free surface becomes a paraboloid. This solution neglects both viscosity and surface tension, and makes the unphysical prediction that the fluid height can become negative beyond a certain critical angular velocity (for a given fluid height). We perform experiments with completely wetting PDMS oil on silcon wafer, where beyond the critical angular velocity, the central region never dewets, but goes to a nominally flat state over long times. The dynamics of the transition to this final state depends on the angular speed and the initial radius of the dewetting region. There is a marked difference in the spin-up and spin-down dynamics. When the completely wetting liquid is replaced by a partially wetting liquid a dry central spot opens up, occasionally leaving a droplet trail. In both cases the contact line does not develop any azimuthal instabilities. Collaboration with Tom Witelski and Mihaela Froehlich.

Monday, March 5, 2007 2:30PM - 5:30PM –
Session D29 DFD: Focus Session: Colloids II Colorado Convention Center 303

2:30PM D29.00001 Imaging the Dynamics of Freezing and Sublimation of Colloidal Crystals[1] , ANTHONY D. DINSMORE, University of Massachusetts Amherst Physics — We study the kinetics of freezing and sublimating colloidal crystals with single-particle resolution. In experiments, a short-ranged depletion attraction between spheres leads to crystallites that are one to three layers thick. The spheres are tracked with optical microscopy and the sizes and bond-orientational order parameters of the crystallites are measured. The inter-particle attraction is reduced or increased by modest changes in temperature, which lead either to sublimation of crystallites or to formation of crystallites from a gas phase. The sublimation process is also investigated using Brownian Dynamics simulations. In both experiments and simulations of sublimation, we find a two-stage process: at first, large crystallites sublimate by escape of particles from the perimeter. The rate of crystallite shrinkage is then greatly enhanced as the size falls below a cross-over value that ranges between 20 and 50 in different regions of the phase diagram. Simultaneous with the enhanced sublimation rate, the crystallites transform to a dense amorphous structure, which then rapidly vaporizes. The two-step kinetics are also seen in freezing at sphere area fractions near 0.3, but not at substantially higher or lower area fractions. The two-step kinetics are attributed to a thermodynamically meta- or unstable amorphous phase (ten Wolde and Frenkel, Science **277**, 1975 (1997).). The results should be relevant in diverse systems including colloids, proteins, and atoms such as Argon. We gratefully acknowledge support from Research Corporation and from the NSF through grant DMR-0605839.

[1]In collaboration with J. R. Savage, D. W. Blair, R. A. Guyer, and A. J. Levine.

3:06PM D29.00002 Dynamics and Instabilities of Defects in Curved Two-Dimensional Crystals[1] , MARK BOWICK, HOMIN SHIN, Syracuse University, ALEX TRAVESSET, Iowa State University and Ames Lab. — Point defects play a fundamental role in determining the thermodynamic, elastic and mechanical properties of two-dimensional crystals. When such crystals are curved, finite length grain boundaries (scars) appear as basic structural features. We discuss an analytical determination of the elastic spring constants of dislocations bound within scars and compare them with existing experimental measurements from optical microscopy. We further show that vacancies and interstitials, which are stable defects in flat crystals, are generally unstable in curved geometries.

[1]The work of MB amd HS was supported by NSF grant ITR-DMR-0219292 and that of AT by NSF grant ITR-DMR-0426597

3:18PM D29.00003 Two-Dimensional Melting of Microgel Colloidal Crystals[1] , YILONG HAN, NA YOUNG HA, AHMED ALSAYED, ARJUN YODH, Department of Physics and Astronomy, University of Pennsylvania — We investigate the phase behavior of 2D colloidal crystals composed of NIPA (N-isopropyl acrylamide) microgel spheres whose diameters can be temperature-tuned. The measurement of a variety of densities of defects, order parameters and correlation functions (static and dynamic) are reported and are in agreement with KTHNY theory at least some of the time. In contrast to previous experiments we use the divergence of translational and rotational susceptibilities (i.e. fluctuations of the corresponding order parameters) to determine the phase transition points. This approach avoids some ambiguities inherent in the other analyses and clearly resolves the intermediate hexatic phase between the solid and liquid phases. Our measurements uncover a novel premelting stage in solid and suggest that traditional analysis methods can incorrectly associate the premelting stage with the hexatic phase. In separate measurements of the melting of two-layer square lattices, we also observed a 'middle' phase.

[1]This work is supported by the MRSEC grant DMR-0520020 and NSF grant DMR-0505048.

3:30PM D29.00004 Angular rheology study of colloidal nanocrystals using Coherent X-ray Diffraction , MENGNING LIANG, University of Illinois Urbana-Champaign, ROSS HARDER, IAN ROBINSON, University College London — A new method using coherent x-ray diffraction provides a way to investigate the rotational motion of a colloidal suspension of crystals in real time. Coherent x-ray diffraction uses the long coherence lengths of synchrotron sources to illuminate a nanoscale particle coherently over its spatial dimensions. The penetration of high energy x-rays into various media allows for in-situ measurements making it ideal for suspensions. This technique has been used to image the structure of nanocrystals for some time but also has the capability of providing information about the orientation and dynamics of crystals. The particles are imaged in a specific diffraction condition allowing us to determine their orientation and observe how they rotate in real time with exceptional resolution. Such sensitivity allows for the study of rotational Brownian motion of nanocrystals in various suspensions and conditions. We present a study of the angular rheology of alumina and TiO2 colloidal nanocrystals in media using coherent x-ray diffraction.

3:42PM D29.00005 Correlated Motion of Rods Diffusing in 3D , KENNETH DESMOND, ERIC R. WEEKS, Emory University — It's well known that micron size particles suspended in a fluid will undergo Brownian motion. This Brownian motion is the result of thermal fluctuations that cause the particles to exhibit both translational and rotational diffusion. Translational diffusion due to Brownian motion has been well studied in the past, but rotational diffusion has not received nearly as much investigation. In our experiments, we observe rotational diffusion using polystyrene ellipsoids suspended in a water glycerol mixture. We have developed an algorithm to detect both the center of mass and orientation of our ellipsoidal particles in 3 dimensions. We examine spatial correlations between rotational and translational motion of pairs of these particles. It's known that the spatial correlation between the translational motion of spherical particles decays as $1/r$ in a homogeneous solution where r is the separation distance between two particles. We are currently investigating the spatial decay of rotational correlation of the colloidal rods.

3:54PM D29.00006 Two-Dimensional Phase Behavior of Colloidal Peanuts , SHARON GERBODE, ANGIE WOLFGANG, STEPHANIE LEE, BETTINA JOHN, CHEKESHA LIDDELL, FERNANDO ESCOBEDO, ITAI COHEN, Cornell University — While the phase behavior of spherical colloidal suspensions has been well studied, the ordering of non-spherical colloidal particles remains a largely unexplored yet important problem. In this talk we will describe ongoing studies of one very simple extension of the spherical particle: the colloidal peanut. These peanuts have an aspect ratio that makes them comparable to dimer particles. Confining the colloidal peanuts to two dimensions, we find that the suspension can undergo a phase transition from a liquid to an ordered phase in which each individual peanut lobe resides on a triangular lattice site. The lobe packing is very similar to the hexagonally close packed crystalline arrangement formed by spheres in 2D. Unlike their spherical counterparts, however, the colloidal peanuts are not isotropic, and in particular, each peanut has a specific orientation, or director. In this talk we will describe the correlations between defects in the underlying triangular lattice and the local director field. We will also report on our measurements of long-range director correlations, and if time permits, we will describe ongoing work relating to phases formed by peanut particles with different aspect ratios.

4:06PM D29.00007 Cage Trapping and Melting of Colloidal Suspensions under Confinement and Shear Excitation , PRASAD SARANGAPANI, Y. ELAINE ZHU, Dept of Chemical and Biomolecular Engineering, Univ.of Notre Dame — The details of the glass transition are still hotly debated. The unusual phenomenon where the viscosity of supercooled fluids diverges near the glass transition without marked structural change is often attributed to a growing length scale of cooperatively rearranging clusters (CRC) of molecules or particles. One way to probe the dynamics of CRC is through confinement, where a glass transition can be observed 'sooner' as film thickness approaches a critical value while temperature and volume fraction remain constant. We study a hard-sphere poly(methyl methacrylate) colloidal suspension to model glassy materials. Using a home-designed micro-rheometer interfaced with a confocal microscope, we visualize the structure and dynamics of confined colloidal thin films between two surfaces at narrow gap spacing ranging from 50 μm to 1-2 μm. Recent experimental evidence has shown that the size of CRC grows dramatically as film thickness approaches an apparent critical dimension of 10-15 particle layers. In preliminary experiments by *in situ* shear force measurements and microscopic characterization, we investigate the re-fluidization or 'melting' of glassy colloidal thin films by applying large shear amplitude and frequency. This phenomenon consequently causes the α and β relaxation regimes to occur sooner compared to un-sheared confined glassy thin films.

4:18PM D29.00008 Phase transitions in charged colloidal suspensions , GREGG LOIS, COREY O'HERN, Yale University — Experiments on charged colloidal suspensions suggest that their structure and dynamics are sensitive to small variations in the amount of charge deposited on each particle. We numerically explore the phase diagram of charged colloidal suspensions for different values of temperature and charge polydispersity. For increasing charge polydispersity we find that the crystalline ground state is no longer accessible at low temperature and the system forms a glass. We compare the dynamic signatures of this state to the properties of hard-sphere colloids with size polydispersity. We also observe spatial and temporal inhomogeneities in the glassy state and examine the length and time scales over which they persist.

4:30PM D29.00009 Coulomb Interactions of Colloidal Particles in Oil , SUNIL SAINIS, Yale University Mechanical Engineering Department, ERIC DUFRESNE, Yale University, Departments of Mechanical Engineering, Chemical Engineering and Physics — We study the electrostatic interactions of microspheres (PMMA-PHSA) in solutions of surfactant (NaAOT) in oil (hexadecane). We directly measure the forces between isolated pairs of particles to extract the particle charge and solvent ionic strength. Over a wide range of surfactant concentrations, the interparticle forces are indistinguishable from unscreened Coulomb interactions. Far above the critical micelle concentration, however, the interactions assume the familiar screened Debye-Huckel form. Long-ranged interactions between micron-sized particles provide a window to study the structure and dynamics of strongly-correlated systems.

4:42PM D29.00010 Computer Simulation of Colloidal Electrophoresis[1] , BURKHARD DUENWEG, VLADIMIR LOBASKIN, KRISHNAN SEETHALAKSHMY-HARIHARAN, CHRISTIAN HOLM, Max Planck Institute for Polymer Research, Mainz — We study the motion of a charged colloidal sphere surrounded by solvent, counterions, and salt ions, under the influence of an external electric field. The ions are modeled as particles which interact dissipatively with a lattice Boltzmann background, such that hydrodynamic interactions are taken into account. Similarly, the colloid is modeled as a spherical array of such point particles. Finite concentration values are taken into account by simulating the system in a box with periodic boundary conditions. In terms of dimensionless reduced parameters, the results compare favorably with experimental data. As a complementary approach, we solve the electrokinetic equations by a finite element method.

[1]supported by DFG-SFB-TR6

4:54PM D29.00011 Structure of highly packed microgel particles , ALBERTO FERNANDEZ-NIEVES, JOHAN MATTSON, HANS WYSS, Harvard University, LIDIA RODRIGUEZ-MALDONADO, University of Almeria (Spain), MANUEL MARQUEZ, Arizona State University, ENRIQUE LOPEZ-CABARCOS, University Complutense of Madrid (Spain), ANTONIO FERNANDEZ-BARBERO, University of Almeria (Spain), DAVID A. WEITZ, Harvard University — We study the structure of concentrated suspensions of ionic microgel particles. In the shrunken state, the particles are essentially charged hard spheres and crystallize at high enough volume fractions. When swollen, however, we find no sings of crystallization, as shown by light and neutron scattering experiments; this is the case irrespective of particle concentration. Instead, the scattered intensity is characterized by the presence of two distinct peaks at low and high scattering wave vectors. Surprisingly, we find that the shift of the peaks follow identical scaling laws with concentration both above and below random close packing. The scaling is different for both peaks indicating they have a different physical origin. While the first maximum seems to be related to the structure of the system, the second peak seems to arise from charge correlations inside the microgel particles.

5:06PM D29.00012 Effective Interactions Between Like-Charged Colloids: The Role of Colloid Charge , STEPHEN BARR, ERIK LUIJTEN, University of Illinois at Urbana-Champaign — We investigate the effect of colloid charge on the interactions between like-charged colloids in the presence of multivalent counterions by means of computer simulations. Because there is a large size asymmetry between the colloids and the counterions, conventional simulation methods are inefficient. In order to overcome this, we extend the generalized geometric cluster algorithm for colloidal suspensions [J. Liu and E. Luijten, Phys. Rev.Lett. **92**, 035504 (2004)] to allow for the efficient simulation of systems with electrostatic interactions. In the presence of multivalent counterions, like-charged attraction between the colloids is found to occur over a window of colloid charges. If the colloid charge is too low, the colloid-counterion attraction is too weak for like-charged attraction to occur, and if the colloid charge is too high, the direct electrostatic repulsion overwhelms the attraction induced by the counterions.

5:18PM D29.00013 Diffusion of charged colloidal particles at aqueous interfaces , PENGER TONG, WEI CHEN, Department of Physics, Hong Kong University of Science and Technology — We report our recent experimental study of Brownian dynamics of weakly charged particles at a water-air interface. Optical microscopy and multi-particle tracking are used to measure the mean square displacement of the interfacial particles. The measured short-time self-diffusion coefficient D_s^s has the form, $D_s^s/D_0 = \alpha(1-\beta n)$, where n is the area fraction occupied by the particles and D_0 is the Stokes- Einstein diffusion coefficient. The values of the fitting parameters α and β are found to be different from those for the three dimensional (3D) colloidal suspensions, indicating that hydrodynamic interactions at the interface have interesting new features when compared with their 3D counterpart. *This work was supported by the Research Grants Council of Hong Kong SAR under Grant No. HKUST603305.

Monday, March 5, 2007 2:30PM - 5:30PM –
Session D30 DFD: Fluid Structure and Properties Colorado Convention Center 304

2:30PM D30.00001 Crystallization-induced fluid flow in polymer melts undergoing solidification[1] , ZHIGANG WANG, DONGHUA XU, CAS Key Laboratory of Engineering Plastics, Institute of Chemistry, CAS, Beijing, 100080 PR China, JACK F. DOUGLAS, Polymers Division, NIST, Gaithersburg, Maryland 20899 USA, KLEP TEAM, NIST TEAM — The formation of 'plastic' polymer materials often occurs under confinement where high pressure imprinting or casting in a mold are involved. To gain insight into this highly non-equilibrium process, we examine the nature of fluid flow that occurs in the non-crystallized regions of melts during spherulitic crystallization by following the movement of tracer particles in isotactic polypropylene films using optical microscopy. We observe a relatively rapid (average particle velocity 13 μm/min at 138 ^{o}C, compared to a spherulite growth rate of 0.86 μm/min) particle movement in the melt until the spherulites become geometrically percolated. We interpret this transient flow to arise from the buildup of local stresses under confinement. Crystallization-induced fluid flow is expected to significantly influence crystal morphology, defect formation and ultimate properties of materials forming by injection molding, pressure imprinting and other processing involving both polymeric and non-polymeric materials where crystallization occurs under confinement.

[1]Supported by Hundred Young Talents Program of CAS and NSFC 10590355.

2:42PM D30.00002 The reversible freezing and melting of colloidal crystal and glass , HUA GUO, GERARD WEGDAM, PETER SCHALL, Van der Waals zeeman Institute,University of Amsterdam, T. NARAYANAN, MICHAEL SZTUCKI, European Synchrotron Radiation Facility, ESRF COLLABORATION — We present the observation of gas-liquid and gas-solid phase transitions in a close density matched system of charge stabilized polystyrene spheres suspended in the quasi binary 3-methylpyridine /H_2O/D_2O mixture. The reversible phase transitions are induced by using the temperature as control parameter. The temperature control parameter can be varied actively and accurately and applied to the same system to study the phase behaviors. The "aggregation" observed by Beysens is in reality a phase transition of the colloidal system. Density matching enables us to observe stable gas-liquid and gas-solid equilibriums. Thus the phases formed could be characterized by the measurement of the structure factor with Small Angle X-ray Scattering (SAXS): dense liquid, glass and face centered cubic (fcc) crystal.

2:54PM D30.00003 The riddle of nanoconfined liquids -solid or liquid?[1] , PETER HOFFMANN, GEORGE MATEI, MIRCEA PANTEA, Wayne State University, SHIVA PATIL, University of Madrid, ASHIS MUKHOPADHYAY, Wayne State University — Using a specially designed Atomic Force Microscope (AFM), we recently found that the mechanical behavior of simple liquids can be surprisingly rich when liquids are confined to only a few molecular layers. Under nanoscale confinement, OMCTS, a model silicone oil, remains liquid at thermal equilibrium while exhibiting molecular layering. However, at the application of a very small squeeze rate of the order of 1 molecular layer/second, elastic ('solidlike') behavior can be induced. On the other hand a different silicone oil, TEHOS, which has a more open molecular structure, behaves 'solidlike' even at very slow squeeze rate and there is an indication, using fluorescence correlation spectroscopy, that it may spontaneously 'solidify' close to a flat solid surface. Shear measurements show that when the liquid is allowed to order between the AFM tip and the substrate, the shear stiffness is enhanced, supporting the notion that these liquids can indeed 'solidify' under certain circumstances.

[1]We are acknowledging support from NSF (Career, DBI) and the Nano@Wayne initiative.

3:06PM D30.00004 Phonons in a One-Dimensional Microfluidic Crystal at Very Low Re , TSEVI BEATUS, TSVI TLUSTY, ROY BAR-ZIV, Weizmann Institute of Science — The development of a general theory for the behavior of a crystal driven far from equilibrium has proved difficult. Microfluidic crystals of water-in-oil droplets provide a convenient means to explore and develop models for non-equilibrium dynamics. Owing to the fact that these systems operate at low Reynolds number (Re), in which viscous dissipation dominates inertial effects, vibrations are expected to be over-damped. Against such expectations, we report the emergence of collective normal vibrational modes (equivalent to acoustic 'phonons') in a 1D microfluidic crystal of droplets at Re$\sim$10-4. These phonons propagate at ultra-low sound velocity of $\sim$100μm/s and frequencies of a few Hz, exhibit unusual dispersion relations markedly different to those of harmonic crystals, and give rise to a variety of crystal instabilities that could have implications for the design of commercial microfluidic systems. First-principles theory shows that these phonons the symmetry-breaking flow field that induces long-range inter-droplet interactions, similar in nature to those observed in other systems including dusty plasma crystals, vortices in superconductors and active membranes.
Nature Physics 2, 743-748 (2006).

3:18PM D30.00005 Synchrotron x-ray ultrafast x-ray imaging on dynamic multiphase flow studies , YUJIE WANG, KAMEL FEZZAA, JIN WANG, KYOUNG-SU IM, Argonne National Laboratory — To overcome the long-exposure time of x-ray imaging for liquid systems. In the past year, we have developed the first ultrafast white-beam synchrotron x-ray phase-contrast imaging technique in the world. With its unprecedented temporal (0.5 μs) and spatial resolutions (1 μm), this new technique has already shown great promises in the study of complex fluid mechanical systems. It can probe complex surface morphology and transient dynamics of these interfaces of fluid mechanical systems without the nuisance of multiple scattering. This technique is a big step forward in comparison to millisecond-temporal and micrometer-spatial imaging resolutions normally achieved at various synchrotron sources. With the development of this new technique, we can already carry out research in fluid mechanical systems in competition with world-leading research groups. Our study of the primary breakup process of a coaxial air-assisted liquid jet revealed that the dynamics is dominated by a "liquid membrane breakup" process instead of a simple "ligament mediated breakup" process owing to our far superior temporal and spatial resolutions. This observation will naturally lead to a cascade idea for the unified treatment of liquid jets, droplets, and liquid membranes breakup mechanism.

3:30PM D30.00006 Circular polarization memory effect in low-coherence enhanced backscattering of light

YOUNG L. KIM, PRABHAKAR PRADHAN, MIN H. KIM, VADIM BACKMAN, Northwestern University, Evanston, IL 60201 —

We experimentally study the propagation of circularly polarized light in the subdiffusion regime by exploiting enhanced backscattering [(EBS), also known as coherent backscattering] of light under low spatial coherence illumination. We demonstrate for the first time, to the best of our knowledge, that a circular polarization memory effect exists in EBS over a large range of scatterers' sizes in this regime. We show that low-coherence EBS signals from the helicity preserving and orthogonal helicity channels cross over as the mean free path length of light in media varies, and that the cross point indicates the transition from multiple to double scattering in EBS.

3:42PM D30.00007 Penetration depth of low-coherence enhanced backscattering photons in the sub-diffusion regime

HARIHARAN SUBRAMANIAN, PRABHAKAR PRADHAN, YOUNG KIM, VADIM BACKMAN, Northwestern University, Evanston, IL 60208 —

The mechanisms of photon propagation in random media in the diffusive multiple scattering regime have been previously studied using diffusion approximations. However, similar understanding in the low-order (sub-diffusion) scattering regime is not complete due to difficulties in tracking photons that undergo very few scatterings events in the medium. Recent developments in low-coherence enhanced backscattering (LEBS) overcome these difficulties and enable us to probe photons that travel very short distances and undergo only a few scattering events. We derive the analytical expression of the probability of penetration depth and most probable penetration depth of photons due to LEBS, and also performed Monte Carlo numerical simulations to support our analytical results. Our results demonstrate that, the most probable penetration depth $z_p$of photons that undergo low-order scattering events have only weak dependence on scattering mean free path $l_s$and anisotropy factor g of the medium, and strong dependence on the spatial coherence length of illumination,L_{sc}. For very small L_{sc} ($<<$ l_s), we show that the penetration depth is proportional to $1/3$ power of the coherence volume, i.e. $z_p \propto \left(l_s \pi L_{sc}^2\right)^{1/3}$. Important implications of our results and its application in biological media are also discussed.

3:54PM D30.00008 Dynamics of Single Polymer Chain in Colloidal Suspensions in Narrow Channels[1]

AMIR AMINI, MARC ROBERT, Rice University —

The self-diffusion coefficient of a linear polymer in a narrow cylindrical channel is calculated. The Polymer is treated as a Gaussian chain in the external potential established by neighboring colloids considered as hard obstacles. The approach is based on the Kirkwood equation, in which the hydrodynamic interactions are taken into account approximately. Monomer-monomer correlation function is obtained via a self-consistent mean-field method.

[1]We acknowledge support from NSF and Welch foundation

4:06PM D30.00009 In Situ Surface Enhanced Infrared Absorption Spectroscopy for the Analysis of the Adsorption and Desorption Process of Au nanoparticles on the SiO2/Si Surface

D. ENDERS, T. NAGAO, T. NAKAYAMA, National Institute for Materials Science, ICORP-JST —

The adsorption and desorption of Au nanoparticles (AuNP) in colloidal D2O suspension on the APTES treated SiO2/Si surface was investigated by in situ ATR-IR spectroscopy. With increasing surface density of AuNP the absorption of the vibrational modes of D2O and of the citrate molecules covering the AuNP increases due to surface enhanced infrared absorption (SEIRA). We show that the adsorption kinetics can be investigated by monitoring in situ the molecular vibrational modes of D2O and the citrate molecules, and furthermore we clarify that the adsorption process can be described very well by a diffusion-limited first-order Langmuir-kinetics model. When exposing a saturated AuNP submonolayer to 2-aminoethanethiol (AET)/D2O solution, the AuNP are removed from the surface and the IR absorption of the D2O vibrational modes become weaker again. Taking into account the time dependencies of the CH and the OD peaks, we propose a microscopic model, where the AET molecules quickly adsorb on the AuNP by replacing most of the precovering citrate molecules exposed to the AET solution. As this takes place, the AuNP are finally removed from the surface.

4:18PM D30.00010 Opening the Pandora's box to understand flow behavior of polymeric fluids.

, SHAM RAVINDRANATH, University of Akron, POUYAN BOUKANY, U, YANGYANG WANG, SHI-QING WANG, University of Akron —

Structure-property relationship has been explored for decades in the context of flow behavior of entangled polymeric liquids. For a long time, it has been assumed that the structure of an entangled polymer, i.e., the entanglement network would experience smooth changes during flow. Using an effective particle-tracking velocimetric (PTV) method recently developed in our lab [1], we found that the nonlinear flow dynamics are associated with an elastic breakdown of the fluid structure. This cohesive failure does not necessarily occur homogeneously in a macroscopic-scale experiment, making it ambiguous to interpret traditional rheological measurements. The presentation complies a whole set of PTV observations to elucidate the physical origin of nonlinear flow phenomena in complex fluids such as polymers. [1] *Phys. Rev. Lett.* **96**, 016001 (2006); *ibid.* **96**, 196001; *ibid.* **97**, 187801.

4:30PM D30.00011 Critical stresses and cracking in thin films of colloidal dispersions

WEINING MAN, WILLIAM RUSSEL, Princeton Univ. —

Colloidal dispersions are often coated on a substrate to leave a uniform thin film after solvent evaporating. However, during drying, a negative capillary pressure develops as the air-water interface is pulled down into the interstices between particles, putting the drying film in tension. The film responds by collapsing normal to the surface but is constrained from shrinking laterally unless cracks open. In this study, we use a high-pressure ultra-filtration device to measure directly the pressure responsible for cracking in uniform films of latex or silica dispersions containing particles of varying radii, avoiding a drying process with edge effects that generate lateral flows and propagating fronts. The results confirm that cracking is controlled by the recovery of elastic energy with the critical pressure increasing with the modulus of the particle, decreasing with film thickness, and independent of particle size. The Griffith's criterion for equilibrium crack propagation along with the nonlinear stress-strain relation provides a necessary, but not sufficient, condition for cracking. When pressure increases beyond the critical value, additional cracks open in qualitative agreement with our elastic energy recovery model. We also find that films with randomly close packed particles crack at a higher pressure than predicted, while those with hexagonally ordered domains particles crack at the critical pressure. These observations suggest an important role for defects that nucleate cracks.

4:42PM D30.00012 A Novel Approach to Extracting the Pair Distribution Function of Bulk Liquids and Liquid Surfaces[1]

DAVID VAKNIN, WEI BU, ALEX TRAVESSET, Ames Laboratory and Department of Physics and Astronomy, Iowa —

The liquid structure factor $S(Q;\alpha)$ of water was measured by synchrotron X-rays in a reflection mode using a liquid surface diffractometer up to $Q \approx 6$ Å^{-1} at various angles of incident beam α. The measurements were conducted at incident beam angles above and below the critical angle for total reflection. We calculated the geometrical and penetration depth corrections to $S(Q;\alpha)$s above the critical angle that collapse them into a single bulk $S(Q)$ within experimental error. A new approach to determining the pair distribution function (PDF) from X-ray measured $S(Q)$ was used to analyze the data. The approach involves the calculation of $S(Q)$ from a model PDF, constructed by a linear combination of Error functions, and refined by non-linear least square fit procedure to the measured $S(Q)$. The advantages of this procedure is that no absolute scaling of the intensity is necessary and the PDF is determined with uncertainties. The methodology is currently implemented to determine the PDF at water and other liquid surfaces.

[1]The work was supported by the DOE, Office of BES under contract number W-7405-Eng-82.

4:54PM D30.00013 Femtosecond movies of water at sub-nanometer lengthscales , ROBERT H. CORIDAN, GHEE HWEE LAI, NATHAN S. SCHMIDT, Dept. of Physics, Dept. of Materials Science & Engineering, F. Seitz Materials Research Laboratory, University of Illinois, Urbana-Champaign, MICHAEL KRISCH, European Synchrotron Radiation Facility, Grenoble, France, PETER ABBAMONTE, Dept. of Physics, F. Seitz Materials Research Laboratory, University of Illinois, Urbana-Champaign, GERARD C. L. WONG, Dept. of Physics, Dept. of Materials Science & Engineering, F. Seitz Materials Research Laboratory, University of Illinois, Urbana-Champaign — The nanometer-scale structure and picosecond-scale dynamics of water are relevant to a wide range of problems in physics, such as the hydrophobic interaction and ion hydration. The behavior of water at these scales has been subject of theoretical and MD studies for decades, and water dynamics has been recently accessed using femtosecond 'pump-probe' optical experiments. We will show that it is possible to image dynamical sub-angstrom density fluctuations in water by extracting the density propagator from the dynamical structure factor measured via high-resolution inelastic x-ray scattering spectra at 3^{rd} generation synchrotron sources.

5:06PM D30.00014 Fluctuation dynamics of water-hydrophobic interface , SUNG CHUL BAE, ADELE POYNOR, STEVE GRANICK, University of Illinois — Previous x-ray reflectivity measurements of the interface between water and hydrophobic surfaces with contact angle $>100^\circ$ indicate the existence of depletion layer. However, x-ray measurements provide little information of the fluctuation dynamics. In this presentation, surface plasmon resonance imaging technique with $<$ 1ms temporal resolution and $< 1\mu$m lateral resolution has been built to investigate interface between water and methyl-terminated gold surface. This technique enables to examine the fluctuation dynamics of the depletion layer with temporal and spatial correlation analysis. The characteristic time and length scales of this fluctuation are explored.

5:18PM D30.00015 Anisotropic polarizability of single wall carbon nanotubes measured via the electro-optical effect , JEFFREY A. FAGAN, BARRY J. BAUER, ERIK K. HOBBIE, NIST — The electro-optical response of 400 nm long single wall carbon nanotubes (SWNTs) suspended in water with single stranded DNA was measured in response to high frequency electric fields. Specifically, the dichroism of the SWNTs at their chirality dependent optical transitions was recorded, allowing for calculation of the induced alignment of the SWNTs by the applied field. The anisotropic polarizability of an individual SWNT chirality can be clearly assigned from this data. Strong alignment with nematic order parameters above 0.5 was achieved at high field strengths. We find anisotropic polarizabilities a factor of five larger than that previously measured for gold colloidal rods and an order of magnitude larger than that previously measured for tobacco mosaic virus (TMV). The characterization of the anisotropic polarizability is a large step towards exploiting this property for the directed manipulation of specific nanotubes.

Tuesday, March 6, 2007 8:00AM - 11:00AM –
Session H29 DFD: Glassy Dynamics and Jamming I Colorado Convention Center 303

8:00AM H29.00001 Dynamic Facilitation in Colloidal Glasses , SCOTT V. FRANKLIN, Rochester Institute of Technology, ERIC R. WEEKS, Emory University — Dense colloidal suspensions share many characteristics with molecular glasses and, because easily visualized, are a model system for investigating the transition to the glassy state. An important feature of glasses is the presence of spatially heterogeneous dynamics; at any given time only a small subset of particles (clusters) are significantly mobile. To explain the origin and spatiotemporal correlation of clusters, Garrahan and Chandler proposed *dynamic facilitation*, in which motion at one location facilitates subsequent (in time) motion at adjacent regions. We use confocal microscopy to investigate dynamic facilitation in binary mixtures of micron-sized PMMA spheres in two and three dimensions. Dynamic facilitation is identified with spatial correlations between the most mobile particles at two subsequent time intervals, a measure used previously by Vogel and Glotzer to analyze simulations of glass-forming liquids. This provides a critical test of how mobility propagates through the sample in space-time and the spatial and temporal correlation of mobile clusters.

8:12AM H29.00002 Excess Vibrational Modes in Model Glasses[1] , NING XU, University of Pennsylvania and University of Chicago, MATTHIEU WYART, Harvard University, ANDREA LIU, University of Pennsylvania, SIDNEY NAGEL, University of Chicago — We performed both theoretical analysis and computer simulations to study the excess low-frequency normal modes (boson peak) for two widely-used model glasses at zero temperature. The onset frequencies for the anomalous modes from the simulations agree very well with predictions from variational calculations based on minimizing the vibrational energy cost of the lowest-frequency anomalous mode. This energy cost originates from the excess interactions per particle over z_c, where $z_c = 2d$ is the minimum number required for mechanical stability in d dimensions. The total z interactions per particle are divided into two classes: z_1 "stiff" interactions determine the structure of the anomalous mode by adding extra nodes; the remaining $z - z_1$ interactions act as a perturbation and increase the vibrational energy of the mode by increasing the restoring force for displacements. Even though both glasses studied have a high number of interactions per particle, $(z_1 - z_c)/z_c$ is always smaller than 0.6, which indicates that the physics of jamming is relevant to the study of the excess normal modes in glasses.

[1]Supported by DE-FG02-05ER46199 and DE-FG02-03ER46088.

8:24AM H29.00003 Combining Coarse-Graining and Density of States Monte Carlo: Application to Ortho-terphenyl , JAYEETA GHOSH, ROLAND FALLER, UC Davis — The non equilibrium transition from liquid to glass is a challenging problem in condensed matter physics. Various techniques have been applied to elucidate the nature of transition without reaching consensus. The relevant time scales near the glass transition are so long that Molecular Dynamics fails. There is much debate whether standard Monte Carlo succeeds can sample phase space near or below the glass transition temperature. We therefore combine advanced techniques to study the system near the glass transition temperature. Based on atomistic models of the small organic glass former Ortho-terphenyl (OTP) we develop a mesoscale model in which each phenyl ring is replaced by a single interaction center. We obtain a structurally coarse-grained model based on Boltzmann inversion of atomistic radial distribution function at various temperatures. As atomistic radial distribution functions are only weakly temperature dependant, the optimization can be performed at any temperature and can be used for a range of temperatures. It turned out that in the glassy range we need to optimize the potential below the glass transition temperature. Once we have a valid mesoscale model we apply the Wang-Landau Density of States Monte Carlo technique to find the density of states for the system. This novel Monte Carlo technique has already been applied to model glass forming materials but not yet to a chemically explicit model.

8:36AM H29.00004 Geodesic path picture for slow dynamics in supercooled liquids , CHENGJU WANG, RICHARD M. STRATT, Department of Chemistry, Brown University, Providence, RI 02912 — How does dynamics dramatically slow down with decreasing temperature in supercooled liquids? We suggest that the answer can be deduced from the geometry of the potential energy landscape. Instead of looking at real dynamical processes associated with barriers hoping, the landscape is characterized by the geodesic (shortest) paths in the *energy landscape ensemble*, which was defined to include all the configurations with a potential energy less than a given value. Within our geodesic path theory, the diffusion constants depend on the typical ratio of the Euclidean distance to the geodesic path length. Computer simulations show that using only this geometric property of the landscape, one can reproduce the dramatic slow down in diffusion constants for the Kob-Andersen model, a typical glassy system.

8:48AM H29.00005 Random Field Ising Model In and Out of Equilibrium , YANG LIU, KARIN DAHMEN, Department of Physics, University of Illinois at Urbana-Champaign, Urbana, IL 61801, USA — We present numerical studies of zero-temperature Gaussian random-field Ising model (zt-GRFIM) in both equilibrium and non-equilibrium. We compare the no-passing rule, mean-field exponents and universal quantities in 3D (avalanche critical exponents, fractal dimensions, scaling functions and anisotropy measures) for the equilibrium and non-equilibrium disorder-induced phase transitions. We show compelling evidence that the two transitions belong to the same universality class.

9:00AM H29.00006 Probing large length scale behavior of spin glasses with patchwork dynamics , CREIGHTON THOMAS, Syracuse University, OLIVIA WHITE, MIT, ALAN MIDDLETON, Syracuse University — Glassy systems equilibrate on timescales that are difficult to reach with direct simulation of dynamics. The characteristic length scale over which fluctuations occur grows sub-logarithmically in time, so examining aging and rejuvenation effects is problematic. In order to probe large length scale dynamics, we use “patchwork dynamics,” in which a patch of size a is selected out of the spin glass and optimized subject to fixed boundaries provided by the neighboring spins to the patch. Using this method, we investigate the large length scale dynamics of the 2D Ising spin glass with Gaussian J_{ij}, as well as the random bond Ising ferromagnet, where equilibration is found on scales longer than a, and the critical point between these two states.

9:12AM H29.00007 Aging and non-Gaussian dynamics in a colloidal glass , GIANGUIDO C. CIANCI, ERIC R. WEEKS, Emory University — As a hallmark of the glassy state of matter, aging has attracted substantial attention, yet it remains a poorly understood phenomenon. It manifests itself by a dependence of the dynamical properties of the sample on the time elapsed since vitrification. The glassy state is also marked by dynamics that are heterogeneous in both time and space, and that exhibit non-Gaussian statistics over moderate to long timescales. We use a density and refractive index matched suspension of micron sized PMMA colloids as a model glassy material. At these length scales, laser scanning confocal microscopy allows us to follow the motion of a few thousand particles in real time and real space. We study the interplay between the timescales at which the dynamics are non-Gaussian and the age of the sample. We also analyze the spatial extent over which the dynamics are heterogeneous and examine the age dependence of this length scale.

9:24AM H29.00008 Replica theory for fluctuations of the activation barriers in glassy systems , JOERG SCHMALIAN, Iowa State University, MAXIM DZERO, Rutgers University, PETER WOLYNES, University of California at San Diego — Using an effective potential approach to self generated glasses we determine the nucleation of entropic droplets in systems with random first order transition and entropy crisis. We demonstrate that fluctuations of the configurational entropy and of the liquid glass surface tension are crucial for an understanding of the barrier fluctuations in glassy systems and thus are responsible for the broad spectrum of excitations and heterogeneous dynamics in glasses. In particular we derive a relation between the length scale for dynamic heterogeneity and the related barrier fluctuations.

9:36AM H29.00009 ABSTRACT WITHDRAWN —

9:48AM H29.00010 Transport in Disordered Reaction-Diffusion Systems , ANDREW MISSEL, KARIN DAHMEN, University of Illinois, Urbana-Champaign — The effects of quenched spatial disorder in the reaction rates on the behavior of reaction-diffusion (RD) models have been difficult to discern, but understanding these effects is essential for predicting the behavior of any real system reasonably well-described by such a model. We present here a step towards an understanding of these effects on transport in RD systems, taking as our model a 1D system in which particles compete ($2A \to A$) and diffuse with spatially homogeneous rates, reproduce ($A \to 2A$) on certain sites (“oases”), and die ($A \to 0$) on all others. We show that predictions from a simplified linear model for the first passage properties between two oases match the results of Monte Carlo simulations; these results, along with some ideas from percolation theory, can be used to make some predictions about the nature of transport across a disordered (many oases) system in higher dimensions.

10:00AM H29.00011 Is microscopic description of inherent structures possible? , VALENTIN A. LEVASHOV, TAKESHI EGAMI, Univ. of Tennessee, RACHEL S. AGA, JAMES R. MORRIS, Oak Ridge National Laboratory — Description of relaxation in a supercooled liquid of N particles using 3N dimensional potential energy landscape (PEL) implicitly favors the idea that the structure is too complex to be described by any microscopic local structural parameters. We addressed this issue by using atomic level stresses (ALS) introduced a while ago as local structural parameters. With MD simulations and the steepest decent method on a model of liquid iron we studied how the distributions of ALS in inherent structures (IS) depend on the original temperature. We found that the ALS of the IS clearly show the crossover and glass transition temperatures. Thus we conclude that relaxation in inherent structures could be described not only by macroscopic, but also by microscopic topological quantities (MTQ). We also found a way to relate the character of fluctuations in MTQ at real temperatures to the energies of the corresponding IS. We found that the mode-coupling temperature is located significantly below the crossover temperature, closer to the glass transition temperature.

10:12AM H29.00012 Self-Organized Criticality Below The Glass Transition: A Computer Simulation[1] , KATHARINA VOLLMAYR-LEE, Bucknell University, ELIZABETH A. BAKER, Emory University — We obtain evidence that the dynamics of a glassy system below the glass transition is characterized by self-organized criticality. To investigate the dynamics of a binary Lennard-Jones system we use molecular dynamics simulations. To study cooperative motion we define single particle jump events via single particle trajectories and identify clusters of jump events which are correlated in space and time. We find string-like clusters whose size is power-law distributed not only close to T_c but for *all* temperatures below T_c, indicating self-organized criticality which is suggestive of a freezing in of critical behavior.

[1]KVL thanks the Institute of Theoretical Physics, University Göttingen, for hospitality and financial support. EAB acknowledges support from NSF Grant No. REU-0097424.

10:24AM H29.00013 Dynamics and effective temperature for a steady-state sheared glass[1] , THOMAS HAXTON, ANDREA LIU, University of Pennsylvania Department of Physics and Astronomy — In a model sheared glass, the slow dynamics near the onset of jamming are shown to be controlled by a well-defined effective temperature $T_{\rm eff}$. We conduct two-dimensional nonequilibrium molecular dynamics simulations of steadily-sheared, densely-packed, bidisperse disks with soft repulsive pairwise interactions in contact with a heat reservoir. We calculate the viscosity and $T_{\rm eff}$ as functions of shear rate $\dot\gamma$ and bath temperature $T_{\rm bath}$. At $\dot\gamma = 0$, the system undergoes a glass transition at $T_{\rm bath} = T_g$. We study the steady state at $\dot\gamma \neq 0$ and $T_{\rm bath} < T_g$. At low $\dot\gamma$, $T_{\rm eff}$ decreases extremely slowly with $\dot\gamma$ and is nearly independent of $T_{\rm bath}$, while the viscosity continues to increase rapidly. The dramatic change in dynamics with a gradual change in effective temperature is reminiscent of the behavior of the quiescent system as temperature is lowered towards T_g.

[1]This work was supported by NSF-DMR-0605044.

10:36AM H29.00014 Observations of shear-induced clusters seen near the colloidal glass transition , DANDAN CHEN, DENIS SEMWOGERERE, ERIC R. WEEKS, Emory University — Many studies of the glass transition focus on structural relaxation arising from thermally induced dynamics. Several of these studies observed isolated clusters of fast-moving particles. We present experimental work that finds similar heterogeneities from mechanically-induced motion applied to a dense colloidal suspension. We study micron-sized PMMA spheres with a volume fraction of approximately 50%. The sample is subjected to shear while simultaneously the dynamics are recorded using fast confocal microscopy. From the resulting 3D movie the trajectories of the individual particles are tracked and the macroscopically imposed shear is subtracted to study the mechanically-induced non-affine particle motion. We find fast-moving cooperative clusters with pronounced motion in the shear direction.

10:48AM H29.00015 System-size dependence of dynamical heterogeneity in a glass-forming liquid , CHANDAN DASGUPTA, SMARAJIT KARMAKAR, Indian Institute of Science — Dynamical heterogeneity in supercooled liquids is often characterized by a space- and time-dependent higher-order correlation function of local density fluctuations and the corresponding susceptibility (the so-called four-point susceptibility). If the growth of this susceptibility as the temperature is decreased towards the ideal glass transition temperature of mode-coupling theory is a consequence of a growing dynamical correlation length, the dependence of this quantity on the system size should exhibit finite-size scaling behavior. We have used constant-temperature molecular dynamics simulations to study the temperature and sample-size dependence of this quantity for a well-known glass-forming liquid (the Kob-Anderson mixture). Our results show the expected finite-size scaling behavior of the four-point susceptibility in the temperature range over which it exhibits a power-law growth. However, the sample-size dependence of the time scale at which the susceptibility peaks does not exhibit conventional finite-size scaling, possibly indicating the presence of effects not captured in mode-coupling theory.

Tuesday, March 6, 2007 8:00AM - 11:00AM –
Session H30 DFD: Liquid Crystals: Experiments and Theory Colorado Convention Center 304

8:00AM H30.00001 Nonphotochemical Laser Induced Nucleation From a Supercooled Thermotropic Liquid Crystal , XIAOYING SUN, BRUCE GARETZ, Polytechnic University, Brooklyn, MICHELE MOREIRA, PETER PALFFY-MUHORAY, Liquid Crystal Institute, KSU, POLYTECHNIC UNIVERSITY TEAM, LIQUID CRYSTAL INSTITUTE TEAM — A nonphotochemical laser induced phase transition was studied in a supercooled 4'-n-pentyl-4-cyanobiphenyl(5CB, also referred to as PCB and K15) liquid crystal system, using linearly polarized ps pulses from a Nd:YAG laser at a wavelength of 532nm. The result shows that light could induce nucleation from the metastable supercooled isotropic phase to the nematic phase in the case of a slow cooling rate and high laser intensity. The director of the induced nematic phase tends to align along the direction of polarization of the light. At the intensities used, there is no observable reorientation of the director once it is in the nematic phase. These experimental results are consistent with a mechanism based on optical Kerr alignment.

8:12AM H30.00002 Stressed liquid crystals for fast phase retardation switching[1] , ANATOLIY GLUSHCHENKO, KEVIN WOOD, ALEX ROCKWOOD, University of Colorado at Colorado Springs, JOHN WEST, GUOQIANG ZHANG, KE ZHANG, LCI, Kent State University, UCCS TEAM, LCI, KSU TEAM — Liquid crystalline materials are an attractive medium for many devices because they produce large electrically controllable shifts of the phase retardation. Relatively thick (10-100 micron) liquid crystal layers are needed for modern devices. However, the speed of these devices is inversely proportional to the square of the LC layer thickness. We must therefore decouple the speed of switching and thickness of the layer. Here we report on the development of stressed liquid crystals (SLCs) to achieve this goal. These new materials consist of a stressed polymer network that imposes unidirectional alignment of a liquid crystal matrix. We induced the stress by shearing the material. As expected from earlier research in PDLCs, shearing greatly reduces the switching time. Unlike the PDLCs the scattering of the films decreases drastically upon shearing. Indeed the SLC materials are optically clear throughout the visible and infrared. The SLC materials are also characterized by essentially no hysteresis and a completely linear voltage response. This greatly simplifies design of the electronics and driving schemes driving. The SLC's performance is determined by the component materials used, their relative concentration and the preparation conditions. We have produced SLC cells that produce almost 20 microns of phase retardation, that switch on and off in several milliseconds. In general the SLC cells require a driving voltage of about 1V/ μm. The SLCs produce the largest phase retardation at the fastest speeds.

[1]This work was supported by Research Corporation

8:24AM H30.00003 Orientational multiplicity and transitions in liquid crystalline droplets , RAJESH GOYAL, MORTON DENN, The Levich Institute, City College of New York, New York 10031 — Orientation distributions in droplets of liquid crystals with homeotropic anchoring are computed with a simulated annealing algorithm that minimizes the free energy of the Oseen-Frank continuum theory. The droplets exhibit multiple orientational steady states that are separated by finite energy barriers over the entire range of the dimensionless ratio of surface to elastic forces, with maximum transition energy densities of the order of 2,000 Pa for a typical liquid crystalline droplet with a spherical radius of 1 micron. The transition energy densities decrease with elongation to spheroidal droplets with aspect ratios of four or more, indicating that droplet elongation is favored to drive surface-induced transitions.

8:36AM H30.00004 Optical Activity Produced by Layer Chirality in Bent-Core Liquid Crystals[1] , LOREN HOUGH, CHENHUI ZHU, MICHI NAKATA, LCMRC, Physics Department, University of Colorado, Boulder, NATTAPORN CHATTHAM, Department of Physics, Faculty of Science, Kasetsart University, Bangkok Thailand, GERT DANTLGRABER, CARSTEN TSCHIERSKE, Institute of Organic Chemistry, Martin-Luther Universit Halle-Wittenburg, NOEL CLARK, LCMRC, Physics Department, University of Colorado, Boulder — Recent observations of large optical activity in chiral smectic liquid crystalline phases formed from achiral bent-core molecules have been attributed to both a helical superstructure and to layer optical chirality (LOC). The LOC model predicts that optical activity is produced by the local chiral layer structure formed by the simultaneous tilt and polar ordering of bent-core molecules (Hough and Clark PRL, 95, 107802 (2005)). The LOC model predicts that optical activity should be present in the well ordered B2 phase. However, in most materials, the optical activity is masked by birefringence. We studied the $\mathrm{SmC}_A\mathrm{P}_A$subphase of GDa104 (Dantlgraber, et al. Chem. Mater. 14, 1149 (2002).), which has a tilt angle of $\sim$45 degrees (orthoconic), and thus very low birefringence. In this system, we directly demonstrate that layer chirality produces optical activity consistent with the LOC model.

[1]NSF MRSEC DMR0213918 and GAANN P200A030179

8:48AM H30.00005 Observation of a possible tetrahedratic phase in bent-core[1] , DAVID WIANT, Kent State University, KRISHNA NEUPANE, SUNIL SHARMA, ANTAL JAKLU, JAMES GLEESON, SAMAEL SPRUNT — Combined measurements of optical birefringence induced by high magnetic fields and dynamic light scattering have been performed on bent-core liquid crystals at temperatures above their clearing points. The results of these measurements provide compelling evidence of a phase transition between two optically isotropic phases that is consistent with the development of a novel "tetrahedratic" form of orientational order.

[1]NSF grants DMR-0606160, DMS-0456221,DMR-9988614, DMR-0084173

9:00AM H30.00006 Giant flexoelectricity of bent-core nematic liquid crystals[1] , JOHN HARDEN, BADEL MBANGA, Chemical Physics Interdisciplinary Program and Liquid Crystal Institute, Kent State University, NANDOR EBER, KATALIN FODOR-CSORBA, Research Institute for Solid State Physics and Optics, Budapest, Hungary, SAMUEL SPRUNT, JAMES GLEESON, Department of Physics, Kent State University, ANTAL JAKLI, Chemical Physics Interdisciplinary Program and Liquid Crystal Institute, Kent State University — Flexoelectricity is a coupling between orientational deformation and electric polarization. We present a direct method for measuring the flexoelectric coefficients of nematic liquid crystals via the electric current produced by periodic mechanical flexing of the NLC's bounding surfaces. This method is suitable for measuring the response of bent-core liquid crystals, which are expected to demonstrate a much larger flexoelectric effect than traditional, calamitic liquid crystals. Our results reveal that not only is the bend flexoelectric coefficient of bent-core NLC's gigantic (more than three orders of magnitude larger than in calamitics) but also it is much larger than would be expected from microscopic models based on molecular geometry. Thus, bent-core nematic (BCN) materials can form the basis of a technological breakthrough for conversion between mechanical and electrical energy.

[1]This work was financially supported by NSF-DMS-0456221, NSF-DMS-0407201, DMR-0606160 and the Hungarian Research Grants OTKA-037336, OTKA-K-61075 and NKFP-128/6.

9:12AM H30.00007 Bent-core fiber structure: Experimental and theoretical studies of fiber stability , C. BAILEY, Liquid Crystal Institute, E. GARTLAND, Dept. of Mathematical Sciences, Kent State Univ., A. JAKLI, Liquid Crystal Institute — Recent studies have shown that bent core liquid crystals in the B7 and B2 phases can form stable freestanding fibers with a so called "jelly-roll" layer configuration, which means that the smectic layers would be arranged in concentric cylindrical shells. This configuration shows layer curvature is necessary for fiber stability. Classically this effect would destabilize the fiber configuration because of the energy cost of layer distortions and surface tension. We propose a model that can predict fiber stability in the experimentally observed range of a few micrometers, by assuming that layer curvature can be stabilized by including a term dealing with the linear divergence of the polarization direction if the polarization is allowed to have a component normal to the smectic layers. We show that this term can stabilize the fiber configuration if its strength is larger than the surface tension. We also propose an entropic model to explain the strength of this term by considering steric effects. Finally we will take results from this model and apply them to better understand experimental findings of bent-core fibers. Financial support by NSF FRG under contract DMS-0456221. Prof. Daniel Phillips, Particia Bauman and Jie Shen at Purdue Univ., Prof. Maria Carme Calderer at Univ. of Minnesota, and Prof. Jonathan Selinger at Kent State Univ. Liou Qiu and Dr. O.D. Lavrentovich, Characterization Facilities, Liquid Crystal Institute, Kent State Univ. Julie Kim and Dr. Quan Li, Chemical Synthesis Facilities, Liquid Crystal Institute, Kent State Univ.

9:24AM H30.00008 Field-induced phase transitions in SmCP phases of bent-core liquid crystals , S. DHAKAL, JONATHAN V. SELINGER, Liquid Crystal Institute, Kent State University — Liquid crystals composed of bent-core molecules have been studied extensively because they exhibit a wide variety of phases with potential applications. The smectic phases of these molecules have polar order in the layer plane due to the close packing. If the molecules are tilted with respect to the layer normal, the combination of tilt and polar order gives the layer chirality. The resulting liquid crystal can be either chiral or racemic (antichiral), even if the molecules are achiral. The reversibility of these two states with the application of electric field implies the possibility of making light shutters from antiferroelectric liquid crystals of bent-core molecules [1]. Extending an earlier model of chiral order [2], we develop a phenomenological theory involving three order parameters: chirality (χ), polarity (P) and tilt (θ) within each layer. By minimizing the free energy, we predict multiple phase transitions ($\mathrm{SmC}_A\mathrm{P}_A \rightarrow \mathrm{SmC}_S\mathrm{P}_F$, $\mathrm{SmC}_A\mathrm{P}_A \rightarrow \mathrm{SmC}_A\mathrm{P}_F$) as a function of electric field, consistent with experiments. [1] A. Jakli *et al.*, *Liq. Cryst.* **29**, 377 (2002). [2] J.V.Selinger, *Phys. Rev. Lett.* **90,** 165501(2003).

9:36AM H30.00009 Theory of "scar" defects in liquid-crystalline films[1] , JONATHAN V. SELINGER, ZHAO LU, Liquid Crystal Institute, Kent State University — Recently, several researchers have studied crystalline order on the surface of a sphere, both theoretically [1] and experimentally [2]. In this system, one might expect to see twelve point disclinations, as required by topology. Instead, they find that the point disclinations extend into "scar" defects, which are finite grain boundaries. Our goal is to determine how general is the phenomenon of scar formation. Does it require crystalline order, and does it require curvature? For that reason, we investigate an xy model in a flat disk geometry, where boundary conditions require a total topological charge of $+1$, i.e. the vector order parameter must rotate through a total angle of 2π. In the classical xy model, the ground state would have a single vortex of charge $+1$. However, for certain slight variations on the xy model, the ground state has a scar defect, which looks like two vortices of charge $+1/2$ connected by an orientational domain wall. The formation of scars depends on details of the interaction energy in a lattice or continuum system. We discuss possible opportunities to observe these scar defects in experiments. [1] M. J. Bowick et al., *Phys. Rev. B* **62**, 8738 (2000). [2] A. R. Bausch et al., *Science* **299**, 1716 (2003).

[1]Supported by NSF Grant No. DMR-0605889.

9:48AM H30.00010 Semi-soft Nematic Elastomers and Nematics in Crossed Electric and Magnetic Fields[1] , FANGFU YE, University of Pennsylvania, RANJAN MUKHOPADHYAY, Clark University, OLAF STENULL, University of Duisburg-Essen, TOM LUBENSKY, University of Pennsylvania — Ideal nematic elastomers exhibit soft elasticity in which an elastic modulus of a uniaxial solid vanishes and in which it takes no stress to produce strains, up to a critical strain, in the direction perpendicular to the uniaxial direction. Elastomers crosslinked while stretched exhibit semi-soft elasticity with a nearly linear stress-strain curve at small strain followed by a nearly flat stress-strain relation up to a critical strain. Semi-soft elasticity above the so-called mechanical critical point, which terminates the line of coexistence of nematic phases, has not been established. We calculate global phase diagrams and stress-strain curves for a series of models, including a generalization of de Gennes-Maier-Saupe (dGMS) model and the neolclassical model for nematic elastomers, and demonstrate that semi-soft behavior can persist well above the mechanical critical point. The dGMS model also describes a normal nematic in perpendicular electric and magnetic fields and exhibits a Blume-Emery-Griffiths tricitical point topology.

[1]Supported in part by NSF grant DMR04-04670.

10:00AM H30.00011 Simulation studies of liquid crystal elastomers: response to light[1] , ROBIN SELINGER, JONATHAN V. SELINGER, BADEL L. MBANGA, Kent State University — Azo-dye doped nematic elastomers bend and flex when subject to photoexcitation. We model this mechanical response at the continuum level using nonlinear finite element simulation. Our finite element algorithm uses explicit dynamics based on a Hamiltonian which couples mechanical strain and nematic order. Our explicit dynamics algorithm is structured essentially like molecular dynamics, and we discuss how this continuum level code can be easily integrated into a multiscale model. We use the model further to explore potential applications of nematic elastomers in microfluidics, fiber orientation control, and biologically-inspired robots.

[1]Supported by NSF-DMR 0605889 and by ACS PRF# 40712-AC 7.

10:12AM H30.00012 Simulation studies of liquid crystal elastomers: soft elasticity[1] , BADEL MBANGA, JONATHAN V. SELINGER, ROBIN SELINGER, Kent State University — Liquid crystal elastomers combine the elastic properties of rubbers with the order inherent in nematic liquid crystals. Stretching a monodomain strip of nematic elastomer in a direction transverse to the nematic director results in an energy-free rotation of the director, giving rise to a soft elastic response. In building a simulation model of this mechanism, we consider the limit in which the orientational order equilibrates rapidly compared to the strain, so that the local order tensor remains in continuously evolving quasi- static equilibrium as the strain relaxes. The order tensor in each volume element is determined by minimizing a free energy functional in the form of a Landau expansion that includes a term coupling the local orientational order with the local strain. The strain evolves via nonlinear finite element explicit dynamics. We intend through this model to further our understanding of the basic physics governing the dynamic mechanical response of nematic elastomers and also provide a useful computational tool for design and testing of potential engineering device applications.

[1]Supported by NSF-DMR-0605889 and ACS PRF# 40712 -AC 7.

10:24AM H30.00013 A dynamical approach for liquid crystal simulations , JONES WAN, Department of Physics, The Chinese University of Hong Kong — A novel, efficient simulation scheme is proposed to determine the liquid crystal configurations under complex physical environments. In this simulation scheme, the liquid crystal elastic energy, the electrostatic interaction, and the surface anchoring effect are calculated by a dynamical approach, which is analogous to molecular dynamics simulation. As a result, various techniques established for molecular dynamics are readily adopted to the proposed scheme. We demonstrate the new method by calculating the director field of a liquid crystal under the effects of an external electric field and patchy pattens.

10:36AM H30.00014 Smectic Defects with Riemann Reason , ELISABETTA MATSUMOTO, RANDALL KAMIEN, CHRISTIAN SANTANGELO, University of Pennsylvania — Minimal surfaces are natural starting points when considering smectics because they minimize the bending energy of the layers. Alternatively, "sums" of screw dislocations have been used to model twist-grain boundaries, and often lead to layers with the same topology as classic minimal surfaces. We use Riemann's minimal surface as a model for a smectic whose layers are joined by pores. We evaluate the energetics of this surface using an explicit phase field representation in terms of elliptic functions. We also build a surface with the same topological structure as Riemann's minimal surface using a configuration of oppositely-charged screw dislocations.

10:48AM H30.00015 Angular momentum transport in soft anisotropic matter[1] , MARK WARNER, Cavendish Laboratory, University of Cambridge, PETER PALFFY-MUHORAY, Liquid Crystal Institute, KSU, MICHAEL SHELLEY, Courant Institute of Mathematical Sciences, NYU, XIAOYU ZHENG, Dept. of Mathematical Sciences, KSU, CAVENDISH LABORATORY TEAM, LIQUID CRYSTAL INSTITUTE TEAM, COURANT INSTITUTE OF MATHEMATICAL SCIENCES TEAM, DEPT. OF MATHEMATICAL SCIENCES TEAM — If an anisotropic crystal is placed in a magnetic field, it will tend to rotate into alignment as a rigid body. An anisotropic sample of soft matter, such as a liquid crystal or a liquid crystal elastomer, will behave differently; initially, only the anisotropic constituents rotate about their centers of mass, then interactions between them give rise to material currents and eventually to rigid body rotation. Since the external field exerts only a body torque – but no force - on the sample, it is interesting to ask how the forces which drive translational motion arise. To gain insight into this problem, we consider the response of a cylindrical liquid crystal sample in a magnetic field in a geometry where both the director and the applied field are perpendicular to the cylinder axis. We solve the equations of motion for low molecular weight liquid crystals and for liquid crystal elastomers and trace the flow of angular momentum in order to understand the details of the dynamics.

[1]This work was supported by the NSF under grant DMR 0606357.

Tuesday, March 6, 2007 11:15AM - 1:51PM –

Session J22 GSNP DFD: Focus Session: Collective Dynamics of Self-Driven Particles Colorado Convention Center 108

11:15AM J22.00001 From cell extracts to fish schools to granular layers: the universal hydrodynamics of self-driven systems[1] , SRIRAM RAMASWAMY, Centre for Condensed Matter Theory, Department of Physics, Indian Institute of Science, Bangalore 560 012 India — Collections of self-driven or "active" particles are now recognised as a distinct kind of nonequilibrium matter, and an understanding of their phases, hydrodynamics, mechanical response, and correlations is a vital and rapidly developing part of the statistical physics of soft-matter systems far from equilibrium. My talk will review our recent results, from theory, simulation and experiment, on order, fluctuations, and flow instabilities in collections of active particles, in suspension or on a solid surface. Our work, which began by adapting theories of flocking to include the hydrodynamics of the ambient fluid, provides the theoretical framework for understanding active matter in all its diversity: contractile filaments in cell extracts, crawling or dividing cells, collectively swimming bacteria, fish schools, and agitated monolayers of orientable granular particles.

[1]Support: DST (through the CCMT) and IFCPAR Project 3504-2.

11:51AM J22.00002 Simulations of Interacting Magnetic Micro-swimmers , ERIC KEAVENY, MARTIN MAXEY, Division of Applied Mathematics, Brown University — Following a recent realization of artificial micro-swimming (Dreyfus et. al., *Nature*, **437**, 862-865), we conduct simulations of a swimmer whose mechanism of propulsion is the magnetically driven undulation of a flagellum-like tail composed of chemically linked paramagnetic beads. In our model, the tail is treated as a series of spheres tied together by inextensible, bendable links. The spheres interact magnetically through mutual dipole interactions, and hydrodynamic interactions are achieved by the force-coupling method. Building on our previous results, we examine the interactions between multiple swimmers employing a flagellum beating strategy as well as those using a rotary propulsion scheme. In addition to swimmer-swimmer interactions, the effects of a nearby surface on the behavior of a micro-swimmer will be discussed.

12:03PM J22.00003 Response and Fluctuations in an Active Bacterial Suspension , ANDY W.C. LAU, Florida Atlantic University, DANIEL T. CHEN, ARJUN G. YODH, TOM C. LUBENSKY, UPenn — An active bacterial bath consists of a population of rod-like motile or self-propelled bacteria suspended in a fluid environment. In this talk, we present a two-fluid model for the dynamics of a bacterial bath, and show, in particular, that the non-equilibrium contribution to the stress arising from the swimming of the bacteria and the non-equilibrium couplings between the alignment tensor and bacterial density, lead to i) a $1/\sqrt{\omega}$ scaling in the power spectrum of the active stress fluctuations, and ii) anomalous density fluctuations in the bacteria themselves. These predictions are observed in a recent experiment.

12:15PM J22.00004 Collective dynamics of concentrated swimming micro-organisms[1] , JOHN O. KESSLER, Physics Dept, University of Arizona, Tucson, Az 85721, LUIS CISNEROS, Physics, Univ. of AZ, RAYMOND E. GOLDSTEIN, DAMTP, University of Cambridge, UK, CHRISTOPHER DOMBROWSKI, Physics, Univ. of AZ — Approximately close packed populations of the cylindrical self-propelled bacteria Bacillus subtilis intermittently form domains of aligned, co-directionally swimming organisms. The velocities of these phalanxes are often "high" compared to the speed of individual swimmers. They vary with the depth of the suspension of organisms. Although the Reynolds number is <1, this collective dynamic phase, the "Zooming BioNematic" (ZBN), appears turbulent. Remarkable spatial and temporal correlations of velocity and vorticity, associated with the spontaneous appearance and decay of these surging phalanxes, were measured using appropriately modified Particle Imaging Velocimetry (PIV). These new data, together with measurements of the trajectories of individual cells, provide ingredients for a rational bio-fluid-dynamical theory of the ZBN.

[1]Work supported by DOE W31-109-ENG38 & NSF PHY 0551742

12:27PM J22.00005 Large scale flows and density fluctuation in ensembles of swimming bacteria[1] , ANDREY SOKOLOV, IGOR ARONSON, Argonne Natl Lab, JOHN KESSLER COLLABORATION, RAYMOND GOLDSTEIN COLLABORATION — We study experimentally self-organization of concentrated ensembles of swimming bacteria Bacilus Subtilis. Experiments are performed in a very thin (of the order of 1 bacterium diameter) fluid film spanned between four supporting fibers. Small amplitude electric field is used to adjust dynamically the density of bacteria inside the experimental cell. Our experiments revealed only gradual increase of the large scale flow correlation length with the increase in number density of bacteria, and no sharp transition. The fluctuation of density of bacteria as a function of thickness of the film was explored.

[1]This work was supported by U. S. DOE grants DE-AC02-06CH11357 (IA) and DE-FG02-04ER46135

12:39PM J22.00006 Chemotaxis and Target Finding using Chemical Echolocation[1] , TOM CHOU, Department of Biomathematics and Mathematics, University of California, Los Angeles, AJAY GOPINATHAN, School of Natural Sciences, University of California, Merced — Chemotaxis is usually modeled by cellular responses to an imposed, exogenous chemoattractant gradient. Here, we consider a scenario in which a single agent releases a chemical that diffuses and is converted to, or signals the production of another chemical upon contact with a target. This secondary chemical can diffuse back to the agent, which uses it as a chemoattractant. We show that this mechanism has interesting features depending on how the probe chemical is produced, and how the product chemoattractant is sensed. Although involving more steps than conventional chemotaxis that relies on a single chemoattractant, we show that this chemical "pinging" mechanism can provide cells with flexibility in regulating behavior and finding different targets.

[1]Supported by the NSF and NIH.

12:51PM J22.00007 Dynamics of Gas-Fluidized Bipolar Rods , L. DANIELS, D. DURIAN, U. Penn — We study a driven, non-equilibrium two-dimensional system consisting of bipolar rods in a gas-fluidized bed. The rods have an aspect ratio of 4 and occupy an area fraction of 42%, chosen both to minimize the effects of ordering as well as to ensure a uniform density of particles across the system. We are able to track the position and orientation of the particles as a function of time. From this, we measure the dynamics of the system with the advantage that our temporal resolution allows us to observe ballistic motion at the shortest time scales. We calculate the mean squared displacement (MSD) in both the lab frame and the particle's frame in which displacements are measured as either perpendicular or parallel to the rod's long axis. In contrast to a comparable system of isotropic particles in which the dynamics are thermal, our system exhibits distinctly athermal behavior. Specifically, the effective temperature along the parallel direction is greater than that along the perpendicular direction. Furthermore, the parallel MSD remains superdiffusive at the longest time scales we are able to measure before the particles have reached the wall whereas the perpendicular component experiences cross-over to diffusive motion. This is emphasized by the power law decay of the velocity autocorrelation function (VAF). In comparison to a thermal fluid, the parallel VAF decays much more slowly whereas the perpendicular VAF decays more rapidly. With these characteristics in mind, ours is a simple experimental system that could be used to compare to biological models of active particles as well as to generalize the framework of statistical mechanics to non-equilibrium, athermal systems.

1:03PM J22.00008 Simulation of suspensions of hydrodynamically interacting self-propelled particles , PATRICK UNDERHILL, JUAN HERNANDEZ-ORTIZ, MICHAEL GRAHAM, University of Wisconsin-Madison — Simulations of large populations of hydrodynamically interacting swimming particles are performed at low Reynolds number in periodic and confined geometries. Each swimmer is modeled as a rod containing beads with a propulsion force exerted on one bead (with an equal and opposite force exerted on the fluid) and excluded volume potentials at the beads. At small concentrations, the swimmers behave analogously to a dilute gas in which the hydrodynamic interactions perturb the ballistic trajectories into diffusive motion. Simple scaling arguments can explain the swimmer behavior as well as the behavior of passive tracer particles. As the concentration increases, the hydrodynamic interactions lead to large-scale collective motion.

1:15PM J22.00009 Hydrodynamics of self-propelled hard particles. , APARNA BASKARAN, Physics Department, Syracuse University, Syracuse, NY 13244 , CRISTINA MARCHETTI, Physics Department, Syracuse University , Syracuse, NY 13244 — Motivated by recent simulations and by experiments on aggregation of gliding bacteria, we study a physical model of the collective dynamics of self-propelled hard particles on a substrate in two dimensions. The particles have finite size, interact via excluded volume and are frictionally damped by the interaction with the substrate. Starting from a microscopic model of dynamics that includes non-thermal noise sources, we derive a continuum description of the system. The hydrodynamic equations are then used to characterize the possible steady states as a function of the particles' packing fraction and examine their stability. Research support by the NSF award number DMR-0305407.

1:27PM J22.00010 Traffic jams in driven intracellular transport on parallel lanes , THOMAS FRANOSCH, TOBIAS REICHENBACH, ERWIN FREY, Arnold Sommerfeld Center for Theoretical Physics (ASC) and Center for NanoScience (CeNS), LMU Munich, Germany — Microtubules, the intracellular tracks for molecular motors like dynein or kinesin, are built of 12-14 parallel lanes. Although it has been revealed that the motor proteins typically remain on one track while proceeding on the microtubule, the statistics of deviations (random lane changes) is so far unknown. We investigate the effects of a small, but finite number of such lane changes by studying driven transport on two parallel lanes with simple site exclusion [1]. As a result, traffic jams emerge in the stationary density profiles, their location can be controlled by the particle fluxes at the boundaries. We obtain analytical results on the shape of the density profiles as well as resulting phase diagrams by a mean-field approximation and a continuum limit.
[1] T. Reichenbach, T. Franosch, E. Frey, Phys. Rev. Lett. 97, 050603 (2006)

1:39PM J22.00011 DNA multi-ring formation via evaporation process , LU ZHANG, SIDDHARTH MAHESHWARI, HSUEH-CHIA CHANG, Y. ELAINE ZHU, Dept. of Chemical and Biomolecular Engineering, Univ. of Notre Dame — We present a study of multi-ring pattern formation of DNA aggregates during the solvent evaporation of a DNA droplet. When the contact line of a droplet is pinned at a solid substrate, a 'coffee ring' pattern is often observed due to the outward flow during evaporation which carries the nonvolatile solute to the edge of the contact line. Here we report a remarkable observation of multiple rings of DNA stain, where stretched DNA molecules connect each ring. We use a high-speed confocal scanning microscope to investigate the kinetics of the multi-ring formation, when DNAs aggregate at the contact-line and cause a stick-slip receding process with periodic depinning of the contact line. A saw-tooth pattern in measured contact angle during droplet evaporation confirms the stick-slip receding dynamics, and a miscible viscous fingering pattern further confirms the stagnation flow responsible for the formation of consecutive rings. We also report a scaling behavior of the multi-ring wavelength with DNA concentration, droplet size and evaporation temperature, consistent with our proposed mechanism.

Tuesday, March 6, 2007 11:15AM - 2:15PM –

Session J29 DFD GSNP: Focus Session: Granular Flows I Colorado Convention Center 303

11:15AM J29.00001 Lateral stripe state in rapid granular flow on an inclined plane , ROBERT ECKE, Los Alamos National Laboratory, TAMAS BORZSONYI, Hungarian Academy of Sciences — Recently longitudinal vortices were reported in a rapid, dilute flow of sand down a rough inclined plane [1]. We present experimental results, showing that a robust stripe state develops at moderate plane inclinations in denser flows, with a structure substantially different from the one observed in dilute flows. We characterize this new type of stripes by measuring velocity profiles, height profiles, light transmission, and average density of the flow. As opposed to the stripes observed in the dilute regime, here the fast moving region corresponds to the maximum of the height profile. The stripe state is detected in the flow of various materials such as sand of different sizes, glass beads of different sizes, and copper particles of various shapes. We show that by increasing plane inclination we get back the dilute regime and the previously reported stripe structure. For sand particles with the diameter of d=0.4 mm the flow properties were extensively measured at six downstream locations. For this case we find an explicit correspondence between the accelerating nature of the flow and the formation of stripes in the dense regime.

[1] Y. Forterre and O. Pouliquen, Phys. Rev. Lett. 86, 5886 (2001).

11:27AM J29.00002 Universality of granular impact dynamics , HIROAKI KATSURAGI, DOUGLAS DURIAN, University of Pennsylvania — We dropped projectiles into granular media from various heights, and measured the dynamics by an optical method with 100 nanometer and 20 microsecond resolution. Data were obtained for 11 different projectiles (including cylinder as well as spheres) and 4 different granular media. The results can all be explained by a stopping force consisting of the sum of two terms: an inertial drag, proportional to velocity squared and independent of depth, and a frictional drag, proportional to depth and independent of speed. The latter scales as the square-root of projectile density and hence is not simply Coulomb friction. We also demonstrate that this stopping force law can explain seemingly-contradictory penetration and dynamics data reported by other researchers.

11:39AM J29.00003 The Liquid Nature of a Granular Jet Hitting a Fixed Target , XIANG CHENG, GERMAN VARAS, DANIEL CITRON, HEINRICH JAEGER, SIDNEY NAGEL, James Franck Institute and Department of Physics, University of Chicago — We perform the granular analog to the 'water bell' experiment [1]. A column of dry spherical glass beads is accelerated by pressurized air through a glass tube to form a high-speed granular jet. When this jet collides with a stationary target disc, we observe the formation of granular sheets and cones enveloping the target similar to those seen when water jets hit a target and subsequently form water bells. The opening angle of the cones is measured as a function of the speed and diameter of the initial granular column and the diameter of the target disc. Under these conditions, dry granular material behaves similarly to a fluid with zero surface tension, i.e., a fluid with infinite Weber number. By decreasing the flux and increasing the size of the granular particles, we observe that the structure formed by the jet becomes more diffuse and the dynamics changes as the particulate nature of the material becomes more apparent. Furthermore, we measure the force impulse exerted on the target during the collision and relate it to the granular ripples formed on the thin ejected granular sheet. [1] C. Clanet, J. Fluid Mech. 430, 111 (2001).

11:51AM J29.00004 Rapid Granular Flows: From Kinetic Theory to Hydrodynamics , V. KUMARAN, Indian Institute of Science — Rapid granular flows are defined as flows in which the time scales for the particle interactions are small compared to the inverse of the strain rate, so that the particle interactions can be treated as instantaneous collisions. We first show, using Discrete Element simulations, that even very dense flows of sand or glass beads with volume fraction between 0.5 and 0.6 are rapid granular flows. Since collisions are instantaneous, a kinetic theory approach for the constitutive relations is most appropriate, and we present kinetic theory results for different microscopic models for particle interaction. The significant difference between granular flows and normal fluids is that energy is not conserved in a granular flow. The differences in the hydrodynamic modes caused by the non-conserved nature of energy are discussed. Going beyond the Boltzmann equation, the effect of correlations is studied using the ring kinetic approximation, and it is shown that the divergences in the viscometric coefficients, which are present for elastic fluids, are not present for granular flows because energy is not conserved. The hydrodynamic model is applied to the flow down an inclined plane. Since energy is not a conserved variable, the hydrodynamic fields in the bulk of a granular flow are obtained from the mass and momentum conservation equations alone. Energy becomes a relevant variable only in thin 'boundary layers' at the boundaries of the flow where there is a balance between the rates of conduction and dissipation. We show that such a hydrodynamic model can predict the salient features of a chute flow, including the flow initiation when the angle of inclination is increased above the 'friction angle', the striking lack of observable variation of the volume fraction with height, the observation of a steady flow only for certain restitution coefficients, and the density variations in the boundary layers.

12:27PM J29.00005 Kinetic theory of hydrodynamic response functions for a dense granular fluid , JAMES DUFTY, Department of Physics, University of Florida, APARNA BASKARAN, Physics Department, Syracuse University, JAVIER BREY, Fisica Teorica, Universidad de Sevilla, Sevilla, Spain — The general response functions characterizing the response of a homogeneous isolated granular fluid to small spatial perturbations in the hydrodynamic fields have been described recently [1]. These response functions are time correlation functions for the Homogeneous Cooling State. Special cases of this class of time correlation functions are the Green - Kubo expressions for the hydrodynamic transport coefficients. In this work, these functions are expressed in terms of reduced singe particle functions that are expected to obey a linear kinetic equation. The functional assumption required to obtain such a kinetic equation and its relationship to the well studied Boltzmann and Enskog kinetic theories of a granular fluid are illustrated in the particular context of the shear viscosity of this fluid. [1] J. W. Dufty, A. Baskaran and J. J. Brey, J. Stat. Mech. L08002 (2006).

12:39PM J29.00006 Velocity correlations in dense granular flows observed with internal imaging[1] , ARSHAD KUDROLLI, ASHISH ORPE, Clark University — We measure the velocity fluctuations in uniform dense granular flows inside a silo using a fluorescent refractive index matched interstitial fluid. The measurements are made in the uniform plug flow region where the flow is dominated by grains in enduring contacts and fluctuations scale with the distance traveled, independent of flow rate. The distributions of the horizontal and vertical displacements for short time scales show fat tails compared to a Gaussian indicating large fluctuations in particle displacements and possible cage breaking. The mean square displacements show an inflection point supporting the presence of caging dynamics. The velocity autocorrelation function of the grains in the bulk shows a negative correlation at short time and slow oscillatory decay to zero similar to simple dense liquids. Weak spatial velocity correlations are observed in the bulk over several grain diameters. The observed correlations are qualitatively different at the boundaries where significant structural ordering in the flowing granular layer is observed.

[1]Supported by the National Science Foundation under grant number CTS-0334587, and by the donors of the Petroleum Research Fund.

12:51PM J29.00007 Lubrication forces in dense granular flow with interstitial fluid: A simulation study with Discrete Element Method , OLEH BARAN, DENIZ ERTAS, THOMAS HALSEY, FUPING ZHOU, ExxonMobil Research and Eng. — Using three-dimensional molecular dynamics simulations, we study steady gravity-driven flows of frictional inelastic spheres of diameter d and density ρ_g down an incline, interacting through two-body lubrication forces in addition to granular contact forces. Scaling arguments suggest that, in 3D, these forces constitute the dominant perturbation of an interstitial fluid for small Reynolds number *Re* and low fluid densityρ. Two important parameters that characterize the strength of the lubrication forces are fluid viscosity and grain roughness. We observe that incline flows with lubrication forces exhibit a packing density that *decreases* with increasing distance from the surface. As the incline angle is increased, this results in a severely dilated basal layer that looks like "hydroplaning" similar to that observed in geological subaqueous debris flows. This is surprising since the model explicitly disallows any buildup of fluid pressure in the base of the flow, and suggests that hydroplaning might have other contributing factors besides this traditional explanation. The local packing density is still determined by the dimensionless strain rate $I \equiv \dot{\gamma} d\sqrt{\rho_g/p}$, where p is the average normal stress, obeying a "dilatancy law" similar to dry granular flows.

1:03PM J29.00008 Geometrical Mechanism for Solid-Fluid transition in a Granular system , ROHIT INGALE, MARK SHATTUCK, Levich Institute, CCNY — We report an experimental investigation of the geometrical mechanism for solid-fluid transition in a quasi-two dimensional granular system. We demonstrate the presence of geometrical structures resembling plane tilings composed of squares and equilateral triangles in our quasi-2D granular fluid. We further show that this tiling structure manifests itself in distinct features in the bond-length and bond-angle distribution functions. These experimental observations coupled with a number of previously reported theoretical and simulation studies strongly support the proposed square-triangle tiling mechanism for 2D melting. These findings present a possible way to explain the observed phase transitions in non-equilibrium granular systems using entropic-like arguments similar to those used for equilibrium hard sphere/disk systems.

1:15PM J29.00009 Swirling Motion in the System of Vibrated Elongated Particles[1] , IGOR ARANSON, Argonne National Laboratory, DMITRII VOLFSON, LEV TSIMRING , University of California, San Diego — We study large-scale collective motion emerging in a monolayer of vertically vibrated elongated particles. The motion is characterized by recurring swirls with the characteristic scale exceeding several times the size of individual particle. Our experiments identified small horizontal component of the oscillatory acceleration of the vibrating plate in a combination with orientation-dependent bottom friction as a source for the swirls formation. We developed a continuum model operating with velocity field and local alignment tensor which is in a qualitative agreement with the experiment.

[1]This work was supported by U. S. DOE grants DE-AC02-06CH11357 (IA) and DE-FG02-04ER46135 (DV,LT)

1:27PM J29.00010 Angle of Repose of Small, Conducting and Non-Conducting Plates , PAUL J. DOLAN, JR., DENISA S. MELICHIAN, Northeastern Illinois University, ALAN FEINERMAN, University of Illinois at Chicago, REBECCA J. CARLTON, Illinois Wesleyan University, KATHY AUGUSTYN, Evergreen Park Community High School, JUSTIN JOHNSON, Illinois Math and Science Academy — We have investigated the behavior of granular collections consisting of laser-cut shapes from conducting and non-conducting paper, with various cross-sectional shapes (square, rectangular, triangular, circular) and in several sizes and aspect ratios. In particular we have measured the Angle of Repose of piles consisting of large numbers of these particles. While the shape of these particles would suggest that these should behave as thin plates, making quite shallow piles, instead we find that the piles are not shallow, and that the piling is remarkably robust to external disturbances. We will compare our results for various types of materials in various shapes, and also compare these results with what we have observed for larger, symmetric particles.

1:39PM J29.00011 Large scale surface flow generation in driven suspensions of magnetic microparticles: Experiment, theoretical model and simulations , MAXIM BELKIN, ALEXEY SNEZHKO, IGOR ARANSON, Materials Science Division, Argonne National Laboratory — Nontrivially ordered dynamic self-assembled snake-like structures are formed in an ensemble of magnetic microparticles suspended over a fluid surface and energized by an external alternating magnetic field. Formation and existence of such structures is always accompanied by flows which form vortices. These large-scale vortices can be very fast and are crucial for snake formation/destruction. We introduce theoretical model based on Ginzburg-Landau equation for parametrically excited surface waves coupled to conservation law for particle density and Navier-Stokes equation for water flows. The developed model successfully describes snake generation, accounts for flows and reproduces most experimental results observed.

1:51PM J29.00012 The Behavior of Ultrafine Particles in the Absence and Presence of External Fields[1] , MEENAKSHI DUTT, University of Cambridge, BRUNO HANCOCK, CRAIG BENTHAM, Pfizer Global R & D, JAMES ELLIOTT, University of Cambridge — Length scales of particles and their surrounding medium strongly determines the nature of their interactions with one another and their responses to external fields. We are interested in systems of ultrafine particles (0.1 - 1.0 micron) such as volcanic ash, solid aerosols, or fine powders for pharmaceutical ihalation applications. We develop a numerical model for these systems using the Derjaguin-Muller-Toporov (DMT) adhesion theory along with the van der Waals attraction between the particles and their contact mechanical interactions. We study the dynamics of these systems in the absence and presence of gravity by controlling the particle size, and thereby, the surface properties of the particles. Finally, we explore the response of these systems to external fields by studying the evolution of the internal microstructure under contant load and shear strain.

[1]Acknowledgements to Pfizer, Inc. for funding

2:03PM J29.00013 Quasi-equilibrium in tapered chains , ROBERT DONEY, Department of Physics, State University of New York at Buffalo and U.S. Army Research Laboratory, SURAJIT SEN, Department of Physics, State University of New York at Buffalo — The approach to equilibrium in 1d lattices is interesting for granular media since temperature is not well-defined and various authors have reported a violation of equipartition. We extend our previous work on shock mitigation in tapered chains to look at energy sharing among spheres and how the system appraoches a so-called quasi-equilibrium. An overlap potential of adjacent particles is used to model the elastic response of spheres under loading and has the form, $V \sim \delta^n$. For spheres, $n = 5/2$ and is known as the Hertz potential. We can also compare results when $n = 2$ which resembles spring-like behavior. It should be noted however, that in both cases the potential has no restoration term and vanishes when adjacent spheres lose contact. We present the velocity statistics for a variety of Hertzian chain configurations as well as fluctuations for the system's total kinetic energy for both $n = 2$ and $n = 2.5$. We find that most particles in these systems exhibit Gaussian velocity distributions and that the kinetic energy fluctuations of the system depend strongly on system size and weakly on tapering of the spheres. Fluctuations do not damp out over long time however, indicating that the steady-state is a type of quasi-equilibrium. Mathematical fits of the mean fluctuations are further provided as functions of system size, tapering, and n.

Tuesday, March 6, 2007 11:15AM - 1:51PM –

Session J30 DFD: Focus Session: Characterizing Spatio-Temporal Complexity in Fluids and Materials Colorado Convention Center 304

11:15AM J30.00001 Topological Analysis of Spatial Temporal Patterns , KONSTANTIN MISCHAIKOW, Rutgers University — It is fairly easy to collect large amounts of high dimensional data describing the time dependent spatial structures of materials or fluids either through experimentation or numerical simulation. In this talk I will describe how techniques from computational topology can be used to reduce both the size and dimension of the data sets and still provide useful statistics for parameter identification, model selection, and quantification of the spacio-temporal complexity of the dynamics. These ideas will be presented in the context of experimental working involving spiral defect chaos for Rayleigh- Benard convection and numerical simulations of stochastic and deterministic Cahn-Hilliard equations.

11:51AM J30.00002 Coarse-grained velocity gradients in turbulence , NICHOLAS OUELLETTE, HAITAO XU, EBERHARD BODENSCHATZ, Max Planck Institute for Dynamics and Self-Organization — In a turbulent flow, energy cascades from large length and time scales, where it is injected into the flow, to small scales, where it is dissipated by the action of molecular viscosity. At small scales, this energy dissipation is characterized by the velocity gradient tensor. At larger scales, however, different dynamics must apply. We therefore present measurements of a velocity gradient tensor coarse-grained over inertial-range scales in an intensely turbulent laboratory water flow. We discuss the potential of these coarse-grained gradients as a probe of the scale-to-scale energy transfer in the turbulent cascade and their relation to Large Eddy Simulation. This work was supported both by the National Science Foundation and by the Max Planck Society.

12:03PM J30.00003 Turbulent-Laminar Patterns in Shear Flows , DWIGHT BARKLEY, University of Warwick — We study computationally turbulent-laminar patterns in very-large-aspect-ratio plane Couette flow. These states consist of large-scale alternations of turbulent and laminar flow oriented obliquely to the steamwise direction. Such flow patterns are now believed to be typical of many transitional shear flows when observed on long length scales. For a fixed pattern orientation of 24^{circ}, suggested by experiment, the basic scenario observed in computations as the Reynolds number is decreased is the following: From uniform turbulence there is a transition to intermittent patterns at $Re \simeq 420$, then to steady, spatially periodic patterns at $Re \simeq 390$. The wavelength increases as the Reynolds number is decreased until $Re \simeq 310$, where the flow consists of localized turbulence within a laminar background. This scenario can depend on pattern orientation – at 90^{circ} with respect to the flow direction, we observe spatio-temporal intermittency in which turbulent patches that repeatedly disappear abruptly and then re-nucleate gradually. We present an analysis of these flows in terms of mean quantities and discuss the difficulties of determining critical bifurcation parameters for such turbulent-laminar systems.

12:15PM J30.00004 Turbulence structures and unstable periodic orbits , GENTA KAWAHARA, Osaka University — Recently found unstable time-periodic solutions to the incompressible Navier-Stokes equation are reviewed to discuss their relevance to near-wall turbulence and isotropic turbulence. It is shown that the periodic motion embedded in plane Couette turbulence exhibits a regeneration cycle of near- wall coherent structures, which consists of formation and breakdown of streamwise vortices and low-velocity streaks. In phase space a turbulent state wanders around the corresponding periodic orbit for most of the time, so that the root-mean-squares of velocity fluctuations of the Couette turbulence agree very well with the temporal averages of those along the periodic orbit. The Kolmogorov universal-range energy spectrum is observed for the periodic motion embedded in high- symmetric turbulence at the Taylor-microscale Reynolds number $Re_\lambda = 67$. Spatio-temporal structures of the periodic solution in high-symmetric flow are investigated to characterize the dynamics of coherent structures which appear in the energy cascade process.

12:27PM J30.00005 Computational Homology in Rayleigh-Benard convection experiments[1] , MICHAEL SCHATZ, HUSEYIN KURTULDU, Georgia Institute of Technology, MARCIO GAMEIRO, KONSTANTIN MISCHAIKOW, Rutgers University — Computational homology is used to analyze the spiral defect chaos (SDC) state in Rayleigh-Benard convection. Image time series of flows visualized by shadowgraphy are used as input; the homology analysis yields Betti numbers, which counts the number of connected components and holes in the flow patterns. Probability distributions and entropies derived from the Betti number measurements are used for identifying and characterizing different states in the SDC regime.

[1]This work is supported by DARPA, DOE and NSF

12:39PM J30.00006 State and Parameter Estimation of Spatio-Temporally Chaotic Systems: Application to Rayleigh-Benard Convection , MATTHEW CORNICK, BRIAN HUNT, EDWARD OTT, University of Maryland, HUSSEIN KURTULDU, MIKE SCHATZ, Georgia Tech — Data assimilation refers to the process of obtaining an estimate of a system's state from a time series of incomplete and noisy measurements along with a model (possibly approximate) for the system's time evolution. Here we demonstrate the applicability of a recently developed data assimilation method, the Local Ensemble Transform Kalman Filter (LETKF), to Rayleigh-Benard convection, a non-linear, high dimensional, spatio-temporally chaotic fluid system. Using this technique we are able to extract the full temperature and velocity fields, including the mean flow, from experimental images of shadowgraphs. In addition, we describe extensions of the algorithm for estimating fluid parameters.

12:51PM J30.00007 Geometric Diagnostics of Complex Patterns: Spiral Defect Chaos in Convection[1] , HERMANN RIECKE, Northwestern University, SANTIAGO MADRUGA, Max-Planck-Institute for Physics of Complex Systems — Motivated by the observation of spiral patterns in a wide range of physical, chemical, and biological systems we present an approach that aims at characterizing quantitatively spiral-like elements in complex stripe-like patterns. The approach provides the location of the spiral tip and the size of the spiral arms in terms of their arclength and their winding number. In addition, it yields as topological information the number of pattern components (Betti number of order 1), as well as their size and certain aspects of their shape. We apply the method to spiral defect chaos in thermally driven Rayleigh-Bénard convection and find that the winding number of the spirals, but not their arclength, is non-monotonic in the heating. The distribution function for the number of spirals is significantly narrower than a Poisson distribution. The distribution function for the winding number decays approximately exponentially. For small Prandtl numbers the analysis reveals a large number of small compact pattern components. Including non-Boussinesq effects, we find that they not only break the up-down symmetry but also strongly increase the number of small, compact convection cells.

[1]Supported by NSF DMS-9804673 and DOE DE-FG02-92ER14303

1:03PM J30.00008 Pattern selection and control via localized feedback , ROMAN GRIGORIEV, Georgia Institute of Technology, ANDREAS HANDEL, Emory University — Many theoretical analyses of feedback control of pattern-forming systems assume that feedback is applied at every spatial location, something that is often difficult to accomplish in experiments. We consider an experimentally more feasible scenario where feedback is applied at a sparse array of discrete spatial locations. We use generalized linear stability analysis to determine how dense the actuator array needs to be to select or maintain control of a given pattern state in the presence of noise. The one-dimensional Swift-Hohenberg equation is used to illustrate our theoretical results and explain earlier experimental observations on the control of the Rayleigh-Bénard convection.

1:15PM J30.00009 Structural analysis of particulate suspensions under simple shear flow[1] , KYUNG AHN, Seoul National University, SUNJIN SONG, SEUNG LEE — A new simulation platform that takes the interaction between fluid and particle has been developed. We analyzed three-dimensional microstructures of repulsive and weakly aggregating suspensions under simple shear flow. Two-dimensional Fourier Transform of the particle images and pair distribution functions were used for microstructure analysis. Particles are well aligned in repulsive suspension while there is an anisotropic configuration of particle clusters in weakly aggregating suspension. We could observe a vorticity-directional motion even in a simple shear flow for aggregating particle suspension, which was recently reported by scattering techniques. Helical motion towards the vorticity direction appears because the flow field is disturbed by the extra stress of the particles. High local shear rate regime is also observed near the fast helical streamlines. This result will provide a clear outlook for the simple shear flow of particulate suspensions.

[1]This work was supported by the National Research Laboratory Fund (M10300000159) of the Ministry of Science and Technology in Korea.

1:27PM J30.00010 Light Propagation in Quasi-Ordered Media , RANDALL TAGG, MASOUD ASADI-ZEYDABADI, University of Colorado at Denver and Health Sciences Center — We evaluate the use of light to probe patterns in optical media whose index of refraction is modulated in the direction of propagation over length scales large relative to the optical wavelength. First, we show how a quadratic index waveguide with periodic axial variations induces a parametric instability in the geometric optics limit. A fundamental scaling allows us to examine a wide range of physical conditions and explore nonlinear behavior such as resonance and chaos. Second, we show that a periodic array of cylinders acts as a waveguide and also shows resonances. We consider the possibility for using these results to probe order-disorder phenomena in systems as widely different as fluid flows and living tissues.

1:39PM J30.00011 Oscillons and reciprocal oscillons[1] , EDGAR KNOBLOCH, JOHN BURKE, University of California at Berkeley, ARIK YOCHELIS, University of California at Los Angeles — Formation of spatially localized oscillations in parametrically driven systems is studied, focusing on the dominant 2:1 resonance tongue. Both damped and self-exciting oscillatory media are considered. The forced complex Ginzburg-Landau equation is used to identify two types of such states, small amplitude oscillons and large amplitude reciprocal oscillons resembling holes in an oscillating background. In addition a variety of front-like states with nonmonotonic profiles is described. A systematic analysis of the origin and stability properties of these states is provided. In many regimes all three states are related to the presence of a Maxwell point between finite amplitude spatially homogeneous phase-locked oscillations and the zero state, leading to a large multiplicity of coexisting stable states of different types.

[1]Research supported by NSF under grant DMS-0305968

Tuesday, March 6, 2007 2:30PM - 5:30PM –
Session L29 DFD: Colloids III Colorado Convention Center 303

2:30PM L29.00001 Clustering instabilities in lattice gas models with isotropic repulsive interactions , PAUL BEALE, MATTHEW GLASER, University of Colorado at Boulder — In previous work we have shown that liquid crystalline order arises in systems of particles with purely repulsive, spherically symmetric pair interactions. We have observed a variety of liquid crystalline phases, as well as rich crystalline and quasicrystalline polymorphism, in simulations of two and three dimensional systems of particles with isotropic pair potentials consisting of an impenetrable hard core plus an isotropic penetrable, repulsive soft shoulder. We have further explored the clustering instabilities in the model by using mean field theory and Monte Carlo simulations of lattice gas models with an isotropic soft-shoulder repulsion that extends out many lattice spacings. The lattice gas model maps exactly onto an Ising model with antiferromagnetic interactions. At low temperatures this repulsive soft shoulder leads to the development of structure on the length scale of the repulsion. Mean field theory predicts both layered and solid structures in the temperature/magnetic field (chemical potential) plane. Monte Carlo simulations display liquid phases with short range patterns, layered incommensurate phases with quasi-long-range order, long- range ordered layered solids, hexagonal micellar solids with quasi- long-range ordering of micelles and long-range ordered hexagonal phases.

2:42PM L29.00002 Structures Formed by Small Numbers of Colloidal Particles Bound to a Spherical Interface , RYAN MCGORTY, VINOTHAN N. MANOHARAN, Harvard University, Department of Physics — We study the behavior of micron sized colloidal particles adsorbed on the interface of spherical droplets not much larger than the colloids. We compare the structures formed by interfacially-bound particles at low particle number to predicted geometries such as the proposed solutions to the Thomson and Tammes problems. The predicted geometries depend critically on the interactions between particles in this low particle number regime. Because all particles on a droplet must be tracked simultaneously, such colloidosome systems have not yet been explored experimentally due to the limited time and z-resolution of confocal and bright-field microscopy. To overcome such limits, we use digital holographic microscopy to locate all particles within a volume of roughly $100\times100\times50$ μm^3 at speeds of up to 500 frames per second. The experimental setup and reconstruction algorithms will be discussed along with our results.

2:54PM L29.00003 Mechanisms of Size and Shape Selection and Control in Self-Assembly of Colloid Particles Synthesized from Nanosize Crystalline Precursors[1] , VLADIMIR PRIVMAN, Clarkson University — The importance of well-defined dispersions of particles of different shapes, ranging in sizes from nanometer to colloidal, has been widely recognized in applications and in basic studies of advanced materials. Our program endeavors to advance understanding of formation of uniform particles of simple and composite structure, with focus on synthesis involving self-assembly of nanosize particles and their new unique properties for dimensions smaller than the typical submicron-size colloid scales. Presently, there is convincing experimental evidence that many monodispersed colloids of various shapes, obtained by precipitation in solutions, are formed by aggregation of such nanocrystalline subunits. Our group's theoretical explanation of this process expands the classical model of formation of uniform particles, by LaMer, and offers an interesting link between nanosize and micrometer size particles.

[1]Web site: www.clarkson.edu/Privman

3:06PM L29.00004 Orientational Order of Chain Forming Ferroelectric Nano Particles in Heptane .[1] , RAMSEY MAJZOUB, LOREN HOUGH, CHEOL PARK, JOE MACLENNAN, NOEL CLARK, Physics Department, University of Colorado at Boulder, ANATOLIY GLUSHCHENKO, Physics Department, University of Colorado at Colorado Springs — Previous computational work [1] has shown that under the appropriate conditions, dipolar spheres aggregate and form chains. In this report, we study nano-sized ferroelectric $BaTiO_3$particles dispersed in heptane. We demonstrate dependence of the particles organization in the colloid *vs.* particles size and concentration. When the particles are large (>40 nm) they sediment to the bottom of the solution; smaller particles (∼10-15 nm) form gels or networks that do not sediment. Probing particle organization by means of freeze fracture electron microscopy reveals that at small sizes ferroelectric particles form a network of chains of particles that have local nematic like order. We compare our observations with the described in literature predictions. [1] J. Weis, D. Levesque Phys. Rev. Lett. 71, 2729 (1993).

[1]This work was supported by NSF MRSEC Grant No. DMR 0213918.

3:18PM L29.00005 Specific and Reversible Assembly of DNA Coated Colloids , REMI DREYFUS, IRMGAARD BISCHOFBERGER, Physics, NYU, RUOJIE SHA, Chemistry, NYU, ANTHONY KIM, JOHN CROCKER, Bio Chem Eng, U Penn, NADRIAN SEEMAN, DAVID PINE, PAUL CHAIKIN, Physics, NYU — We aim to create a new class of materials that self-assemble and self-replicate. Biotin-terminated DNA strands are attached to neutravidin coated polystyrene particles via the well established avidin-biotin coupling mechanism. The DNA is composed of a 61-base strand and a 50-base complementary strand, leaving a single sticky end of 11 bases to interact with its complement attached to another particle. Complementary particles mixed together aggregate into fractal structures. Increasing the temperature leads to dehybridization of the DNA strands and disaggregation of the particles. A typical cycle of aggregation, disaggregation, and reaggregation, as investigated by videomicroscopy, takes ∼ 20 minutes and has been repeated more than a dozen times. Our melting curves are sharp and show a strong dependence with buffer concentration. In a highly ionic environment, the aggregation is well described by a diffusion limited process and slows down considerably as the aggregation temperature approaches the melting temperature. We show how these materials are promising for creating new self-replicating structures.

3:30PM L29.00006 Search for Optical Binding with Shape Phase Holographic Optical Trapping , YOHAI ROICHMAN, MARCO POLIN, ILIAS CHOLIS, DAVID GRIER, Center for Soft Matter Research, Physics Department, New-York University — Light scattered by an illuminated particle should repel that particle's neighbors through radiation pressure. Nearly two decades ago, Burns, Fournier and Golovchenko (BFG) proposed that the coherent superposition of scattered fields can lead to an attractive interparticle interaction, which they called optical binding. Their pioneering experimental observation has generated considerable interest, most of which has focused on developing the theory for the effect. Accurate measurements of the optical binding force in the BFG geometry have been lacking, however. The need to quantify optical binding forces is particularly acute for colloidal interaction measurements on linear optical traps. We present a new method to directly measure optical binding forces between colloidal spheres that exploits the ability of shape-phase holography to create linear optical traps with accurately specified intensity and phase profiles. Our ability to control the trap's phase profile makes possible precise discrimination between intensity- and field-dependent interactions, i.e. between radiation pressure and optical binding. The same novel technique that allows us to project holographic line traps also can be used to project two- and three-dimensionally structured ring traps, novel Bessel-beam traps, which we also will describe.

3:42PM L29.00007 Segregation of Defects at Grain Boundaries. , AHMED M. ALSAYED, ARJUN G. YODH, University of Pennsylvania — Interstitial impurity segregation at grain boundaries plays an important role in materials properties such as cohesion, grain growth kinetics, and transport. Unfortunately, direct measurement of grain boundary composition is difficult in bulk crystals and polycrystals. In this contribution we directly study impurity segregation at grain boundaries using a model colloidal crystal. The polycrystals are made of temperature-sensitive micron size NIPA microgel particles [1]. We add 100-200 nm fluorescent polystyrene particles to this system to model interstitial impurities. The impurities are then tracked using video microscopy close to and far from the grain boundaries. We find that impurities hop from one position to another and diffuse anisotropically when far from the grain boundaries, and they diffuse isotropically in the grain boundaries. Upon increasing the temperature, the packing volume fraction of NIPA particles decreases and grain boundaries start to melt. We also explored the effects of the segregated impurities on grain boundary melting. [1] A. M. Alsayed, M. F. Islam, J. Zhang, P. J. Collings, A. G. Yodh, Science 309, 1207 (2005). This work was supported by grants from NSF (DMR-0505048 and MRSEC DMR05-20020) and NASA (NAG8-2172).

3:54PM L29.00008 Realizing Colloidal Artificial Ice on Arrays of Optical Traps , ANDRAS LIBAL, University of Notre Dame, CHARLES REICHHARDT, CYNTHIA REICHHARDT, Los Alamos National Laboratory — We demonstrate how a colloidal version of artificial ice can be realized on optical trap lattices. Using numerical simulations, we show that this system obeys the ice rules and that for strong colloid-colloid interactions, an ordered ground state appears. We show that the ice rule ordering can occur for systems with as few as twenty-four traps and that the ordering transition can be observed at constant temperature by varying the barrier strength of the traps.

4:06PM L29.00009 Shear Events in Colloidal Glasses , PETER SCHALL, University of Amsterdam, DAVID A. WEITZ, FRANS SPAEPEN, Harvard University — We analyze shear events that occur in sheared amorphous colloidal suspensions. We use the three-dimensional particle positions determined by confocal microscopy to determine irreversible local rearrangements that give rise to high local strain. These shear regions show a long-range strain field characteristic of dipolar strain events. Large displacements of only one or a few particles in the shear event core are enough to stabilize the new configuration and lead to permanent deformation. We will elucidate the interplay between thermal fluctuations and local strain that drives the nucleation of these shear regions.

4:18PM L29.00010 Hydrodynamic Forces in the Lubrication Regime: A Molecular Dynamics Study[1] , SIVAKUMAR R. CHALLA, MILENA USABIAGA ZABALETA, MARC INGBER, University of New Mexico, FRANK VAN SWOL, Sandia National Laboratories — We report on classical molecular dynamics simulations of large spheres moving toward a flat substrate and large spheres moving toward each other. The simulations are designed to investigate hydrodynamics at the molecular scale. We show a new decomposition approach appropriate for force microscopy measurements, and extract the static and dynamic components of the total force from approaching- and receding-force curves that are obtained from simulations or experiments. The dynamic force is evaluated for a range of sphere sizes and approach velocities, with different fluids and as well as with different surface characteristics - smoothness, roughness, and compliance. A comparison with hydrodynamic predictions for the dynamic force is made for these various cases.

[1]Supported in part by the DOE Office of Science's ASCR program in Applied mathematical Sciences. Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed-Martin Company, for the U.S. DOE under Contract No. DE-AC04-94AL85000.

4:30PM L29.00011 Colloid-Polymer Demixing in the Protein Limit: A Simulation Study[1] , BEN LU, ALAN R. DENTON, North Dakota State University — Mixtures of hard colloidal particles and nonadsorbing polymers can exhibit entropy-driven demixing into colloid-rich and colloid-poor phases. The classic Asakura-Oosawa-Vrij (AOV) model idealizes the polymers as effective spheres that are mutually noninteracting but impenetrable to the colloids. Here the AOV model is adapted to the protein limit by assuming the polymers to be (1) penetrable to the smaller colloids (or nanoparticles) and (2) polydisperse in size (radius of gyration). Using Gibbs ensemble Monte Carlo simulation, we explore the influence of the colloid-polymer penetration energy profile on the demixing instability and polymer size distribution. Structural and thermodynamic properties (radial distribution functions, osmotic pressures, and demixing phase diagrams) are computed and compared with predictions of density-functional theory.[2]

[1]Supported by National Science Foundation grant DMR-0204020.
[2]M. Schmidt and M. Fuchs, *J. Chem. Phys.* **117**, 6308 (2002).

4:42PM L29.00012 Colloidal Electrostatic Interactions Measured on Holographic Line Traps , MARCO POLIN, YOHAI ROICHMAN, DAVID GRIER, Center for Soft Matter Research, New York University — We measure the electrostatic colloidal interaction between two colloidal particles diffusing in water along a quasi-1D potential that we generated by shape-phase holography. Interparticle potential measurements are affected in principle by light-induced contributions generated by the confining potential. We present both a measurement of such effect and a method to correct for it without the need for an independent measurement. Fast and accurate measurements on a line tweezer have the potential to become a standard method for assessing locally both equilibrium and out-of-equilibrium processes.

4:54PM L29.00013 Phase Behavior of Charged Colloids: Closed versus Donnan Equilibrium[1] , ALAN R. DENTON, North Dakota State University — The influence of chemical boundary conditions on thermodynamic properties of deionized charge-stabilized colloidal supensions is analyzed. Effective electrostatic interactions and phase behavior are shown to depend fundamentally on whether a suspension is confined to a closed (electroneutral) cell or is in Donnan equilibrium with a microion reservoir, *e.g.*, electrolyte solution. Linear-response theory[2] predicts that at low ionic strength closed suspensions of highly charged macroions and monovalent microions can phase separate, while microion exchange with a reservoir stabilizes the fluid phase.

[1] Supported by National Science Foundation grant DMR-0204020.
[2] A.R. Denton, *Phys. Rev.* E **73**, 41407 (2006).

5:06PM L29.00014 Epitaxial Growth of Thin Colloidal Films in the Presence of a Depletant , ITAI COHEN, MARK BUCKLEY, SHARON GERBODE, Cornell University, ERICA PRATT, Carnegie Mellon University, JALINA KEELING, Austin College — We describe the epitaxial growth of thin films comprised of hard-sphere colloidal particles sedimenting in the presence of a depletant polymer. The depletant polymer induces an effective attraction between microspheres, causing them to nucleate islands that grow and coalesce with one another. In addition, we use photolithography to control the morphology of the substrate. This allows us to investigate the effects of the underlying substrate structure on the epitaxial growth process. Using confocal microscopy, we image and track the colloidal particles as they diffuse, aggregate and rearrange their configurations during deposition. Island density and degree of layer-by-layer growth are determined as functions of the deposition rate and depletant concentration. The ease with which we are able to image deposition in real time and the similarity of our results to those obtained in atomic deposition experiments suggest that our system will allow us to model various processes that occur in atomic thin film epitaxial growth.

5:18PM L29.00015 Patterning Colloidal Films via Evaporative Lithography , DANIEL HARRIS, University of Illinois at Urbana-Champaign, HUA HU, Corporate Engineering Technical Lab, The Procter and Gamble Company, JENNIFER LEWIS, University of Illinois at Urbana-Champaign — We investigate evaporative lithography as a route for patterning colloidal films during drying. Specifically, films composed of mixtures of silica microspheres and polystyrene nanoparticles are patterned by placing a mask above the film surface to induce periodic variations between regions of free and hindered evaporation. Fluorescence and confocal microscopy, coupled with surface profilometry measurements, reveal that particles segregate laterally within the drying film, as fluid and entrained particles migrate towards regions of higher evaporative flux. The colloidal films exhibit remarkable pattern formation that can be regulated by carefully tuning the initial suspension composition, separation distance between the mask and underlying film, and mask geometry.

Tuesday, March 6, 2007 2:30PM - 5:30PM –
Session L30 DFD: Micro and Nano Fluidics Colorado Convention Center 304

2:30PM L30.00001 Microfluidic droplets and electric fields , PATRICK TABELING, CNRS, LAURE MENETRIER, ESPCI, ALICE MCDONALD, MIT, HERVE WILLAIME, CNRS, DAN ANGELESCU, Schlumberger — Manipulating droplets through mazes of microchannels is a challenge faced by digital microfluidics (i.e microfluidics based on droplets). In this domain, using electric fields is an option. This option is justified by the fact that producing large electric fields in miniaturized systems is feasible, and dielectric contrasts between dispersed and continuous phases are typically large. Examples of devices reported in the literature are droplet guides, droplet mergers. In the present paper, we extend this approach by reporting two novel examples of droplet manipulations that exploit the action on an electric field in a microfluidic system: one is the control of droplet emission frequencies and the other is the inhibition of droplet breakup. Throughout the work, we analyze in some detail the various aspects of the action of the electric field. The experiments are performed in PDMS microfluidic systems using hexadecane and water for the continuous and dispersed phases respectively.

2:42PM L30.00002 Chemotaxis in Microfluidic Devices: What does a cell see? , CARSTEN BETA, TONI FROEHLICH, GABRIEL AMSELEM, EBERHARD BODENSCHATZ, MPI for Dynamics and Self-Organization, Goettingen — The use of microfluidic devices is increasingly popular in the study of chemotaxis due to the exceptional control of the flow field and the concentration profiles on the length scale of individual cells. One aspect often forgotten is that the cells are attached to the inner surfaces of the microfluidic channel. The flow field is perturbed and distorted as the fluid is flowing around/over the cells. Depending on the flow speed and dynamics (steady flow - increasing flow - decreasing flow) the cell membrane is not exposed to the "nominal" concentration profiles, but may see a very different signal. The underlying physics will be discussed and "optimal" flow conditions will be identified.

2:54PM L30.00003 Active microfluidic mixing based on transverse electro-osmotic flows[1] , NICHOLAS S. LYNN JR., Department of Chemical and Biological Engineering, Colorado State University, CHARLES S. HENRY, Department of Chemistry, Colorado State University, DAVID S. DANDY, Department of Chemical and Biological Engineering, Colorado State University — As with their macroscale counterparts, laminar fluid mixing becomes a very important, albeit inherently difficult step at the microscale. Micromixers based on electro-osmotic flow (EOF) rely on either a modification of microchannel geometries or a modification of the ζ-potential of the microchannel surfaces to enhance fluid mixing. Here we present a new method of achieving chaotic advection in microchannels by applying an electric field perpendicular to the mean flow direction driven by a pressure gradient in a planar rectangular microchannel. EOF on microchannel surfaces in a direction orthogonal to the main channel axis is generated via an electric field produced by integrated electrodes at the corners of a microchannel. By using serial combinations of different mixing cycles, we show that complete mixing can occur in straight microchannels of length scales on the order of a millimeter. Computational fluid dynamics (CFD) is used to characterize and optimize the mixing efficiency of the system and to compare with experimental measurements.

[1]NIH EB00726

3:06PM L30.00004 Microfluidic bubble logic and applications[1] , MANU PRAKASH, NEIL GERSHENFELD, MIT — We present a novel all-fluidic logic family operating at low Reynolds numbers in newtonian fluids. A bubble in a microfluidic channel represnets a bit. Nonlinearities are introduced in an otherwise linear, reversible flow by bubble-bubble interactions. This allows us to simultaneously perform chemistry and process control without external control elements. A toggle flip-flop, AND/OR/NOT gates, ring oscillator and an electro-bubble modulator will be presented. Applications in high-throughput screening and combinatorial chemistry will be highlighted.

[1]Supported by Center for Bits and Atoms, NSF Grant NSF CCR-0122419

3:18PM L30.00005 Using patterned surfaces to sort elastic microcapsules , ALEXANDER ALEXEEV, ROLF VERBERG, ANNA C. BALAZS, Chemical Engineering Department, University of Pittsburgh — For both biological cells and synthetic microcapsules, mechanical stiffness is a key parameter since it can reveal the presence of disease in the former case and the quality of the fabricated product in the latter case. To date, however, assessing the mechanical properties of such micron scale particles in an efficient, cost-effective means remains a critical challenge. By developing a three-dimensional computational model of fluid-filled, elastic spheres rolling on substrates patterned with diagonal stripes, we demonstrate a useful method for separating cells or microcapules by their compliance. In particular, we examine the fluid-driven motion of these capsules over a hard adhesive surface that contains soft stripes or a weakly adhesive surface that contains "sticky" stripes. As a result of their inherently different interactions with the heterogeneous substrate, particles with dissimilar stiffness are dispersed to distinct lateral locations on the surface. Since mechanically and chemically patterned surfaces can be readily fabricated through soft lithography and can easily be incorporated into microfluidic devices, our results point to a facile method for carrying out continuous "on the fly" separation processes.

3:30PM L30.00006 Lab-on-a-chip Single Particle Dielectrophoretic Traps , WEINA WANG, HUA SHAO, KEVIN LEAR, Electrical & Computer Engineering Department, Colorado State University, Fort Collins, CO 80523-1373 — Cell-patterning and cell-manipulation in micro-environments are fundamental to biological and biomedical applications, for example, spectroscopic cytology based cancer detection. Dielectrophoresis (DEP) traps with transparent centers for stabilized cell and particle optofluidic intracavity spectroscopy (OFIS) were fabricated by patterning 10 μm wide, planar gold electrodes on glass substrates. The capturing strength of DEP traps was quantified based on the minimum AC voltage required to capture and hold varying diameter polystyrene or was it some other material, e.g. silica or PMMA microspheres in water as a function of frequency required under a constant flowrate of 20 μm/s. The maximum required trapping voltage in the negative DEP regime of $f = 1$ kHz to 40 MHz was 5.0 VAC. The use of AC fields effectively suppressed hydrolysis. New geometries of DEP traps are being explored on the basis of 3-D electrostatic field simulations.

3:42PM L30.00007 Hybrid CMOS / Microfluidic Systems for Cell Manipulation with Dielectrophoresis , TOM HUNT, Harvard Physics, DAVID ISSADORE, ROBERT M. WESTERVELT, Harvard DEAS — A hybrid CMOS/microfluidic chip combines the biocompatibility of microfluidics with the built-in logic, programmability, and sensitivity of CMOS integrated circuits (ICs)[1] We have designed a CMOS IC for moving individual cells using dielectrophoresis (DEP). The IC was built in a commercial foundry and we subsequently fabricated a microfluidic chamber on the top surface. The chip consists of a 1.4 by 2.8mm array of over 32,000 individually addressable 11x11 micron pixels. An RF voltage of 5V at 10MHz can be applied to each pixel with respect to the conductive lid of the microfluidic chamber, producing a localized electric field that can trap a cell. By shifting the location of energized pixels, the array can trap and move cells along programmable paths through the microfluidic chamber. We show the design, fabrication, and testing of the hybrid chip. Bringing together the biocompatibility of microfluidics and the power of CMOS chips, hybrid CMOS / microfluidic systems are an exciting technology for biomedical research. Thanks to NSEC NSF grant PHY-0117795 and the NCI MIT-Harvard CCNE. [1] H Lee, Y Liu, RM Westervelt, D Ham, IEEE JSSC 41, 6, pp. 1471-1480, 2006

3:54PM L30.00008 Optical Chromatography of Bacterial Spores , STEVEN SUNDBECK, ALEX TERRAY, JONATHAN ARNOLD, TOMASZ LESKI, SEAN HART, US Naval Research Laboratory — The technique of optical chromatography uses a laser mildly focused against fluid flow in a microfluidic channel to trap microscopic particles. Particles in the channel near the focal point of the laser are drawn toward the beam axis and then accelerated via optical pressure against the fluid flow, reaching an equilibrium point when the optical and fluidic forces on the particle are balanced. This equilibrium point may occur at differing distances from the focal point for microscopic particles with differing properties, such as size, shape, morphology, and refractive index. Thus, identification and separation of particles may be achieved in the system. Optical chromatography may be used as a detection technique for biological particles of interest, either directly or as a means of concentrating and filtering a sample. Of particular interest would be reliable methods for detection of *Bacillus anthracis*, a common weaponized biological agent. In this work we present optical chromatography experiments on bacterial spores which may be environmentally present with *B. anthracis* spores and interfere with detection.

4:06PM L30.00009 "Nanonails" – a Simple Geometrical Approach to "Superlyophobic" Surfaces , TOM KRUPENKIN, AMIR AHUJA, ASHLEY TAYLOR, ALEX SIDORENKO, TODD SALAMON, EDGAR LABATON, Bell Labs, Lucent Technologies — Modern nanofabrication techniques allow creation of a wide range of sophisticated surface topographies that strongly enhance wetting properties of solids. Such surfaces serve as a basis for so-called superhydrophilic and superhydrophobic materials that demonstrate a range of remarkable properties. In both of these cases the topography acts to "amplify" the type of wetting behavior, which is already determined by the surface energies of the liquids and solids involved. In this work we propose and experimentally demonstrate a unique three-dimensional nano-scale geometry that dramatically extends the influence of topography on the wetting properties of the substrate. Using this approach we are able to transform ordinary Teflon-like fluoropolymer surfaces, which are readily wetted by the majority of common low-surface tension liquids into nanostructured substrates with profound superlyophobic behavior. The resulting surfaces are essentially non-wetting and support highly mobile liquid droplets with contact angles close to 150° for a wide variety of liquids with surface tensions ranging from 72.0 mN/m (water) to 21.8 mN/m (ethanol). The proposed approach provides a simple, material-independent method for creating practically useful superlyophobic surfaces.

4:18PM L30.00010 Double Emulsions through Wettability Control in PDMS Microfluidic Devices[1] , CHRISTIAN HOLTZE, Harvard University, ELISA MELE, Universita' degli Studi di Lecce, DAVID WEITZ, Harvard University — Hydrodynamic Flow Focusing allows for the well-controlled production of monodisperse double and multiple emulsions. While this method of emulsification is well described for glass capillary devices, it has not yet been developed for PDMS devices that are readily accessible using soft-lithography. The reason is the difficulty of spatially controlling the wetting behavior of PDMS microchannels. We will present a novel technique of photopatterning that allows for the production of double emulsions in PDMS devices. Moreover, owing to an optimized setup, smaller droplets may be made down to a size range that was not accessible using the conventional approaches.

[1]Deutsche Forschungsgemeinschaft (DFG).

4:30PM L30.00011 Atomistic simulation study of charge inversion in silica nanochannels[1] , CHRISTIAN D. LORENZ, ALEX TRAVESSET, Department of Physics and Astronomy, Iowa State University and Ames Laboratory — Recent experiments report charge inversion, i.e. interfacial charges attracting couterions in excess of their own nominal charge, in divalent ionic solutions near charged silicon oxide interfaces. We have conducted a series of atomistic molecular dynamics simulations in order to investigate the mechanism of charge inversion in these systems. We studied both $CaCl_2$ and $MgCl_2$ solutions near an amorphous silica substrate which had a charge density of $\sim 1/50\text{Å}^2$. Our simulation results give a detailed description of the structure of the ions and water near the silica interface. Finally, we show that our simulations are in remarkable agreement with the experimental results.

[1]This work is supported by NSF grant DMR-0426597 and partially supported by DOE through the Ames Lab under contract # W-7405-Eng-82.

4:42PM L30.00012 Ion solvation in confined water: A first-principles molecular dynamics investigation , ERIC SCHWEGLER, Lawrence Livermore National Lab, GIANCARLO CICERO, Polytechnic of Torino, Italy, JEFFREY GROSSMAN, UC Berkeley, FRANCOIS GYGI, GIULIA GALLI, UC Davis — The importance of water in many areas of science has motivated an enormous number of experimental and theoretical investigations. While the properties of bulk liquid water have been relatively well characterized, much less is known about the properties of water when it is confined in a nanoscale environment. We have carried out a series of first-principles molecular dynamics simulations in order to examine how the solvation properties of simple ions are modified upon nanoscale confinement. These simulations include the aqueous solvation of cations contained within a carbon nanotube. By comparing to the properties of ions in bulk liquid water, the dynamical and structural characteristics of confined ion solvation will be discussed in detail. This work was performed under the auspices of the US Department of Energy by the University of California at the LLNL under contract no W-7405-Eng-48.

4:54PM L30.00013 Measurement of the growth rate of the breakup instability of a propane nanobridge using molecular dynamics simulations , WEI KANG, UZI LANDMAN, School of Physics, Georgia Institute of Technology — Understanding the instability of a nanojet or a nanobridge is of importance for the design of nanoscale fluid devices. Examination and determination of the whole growth rate curve of the instability in these nanostructures is a theoretical challenge. Using large scale molecular dynamics (MD) simulations at 185K we determined the growth rate curve of a nanoscale liquid propane nanobridge of a 0.3 micron length and a 6-8 nm diamater; the system consistes of 340,000 particles. We analyzed, using a discrete spatial Fourier transform, the time evolution of small sinusoidal perturbations of various wavelengths applied to the fluid nanobridge. The large length-to-diameter ratio of our systems allows us to achieve suffcient wavelength resolution. The results of 100 independent simulations were averaged to reduce fluctuation noise. The results were compared with both Rayleigh's and Chandrasekhar's theories and we conclude that the latter is a better fit to our data.

5:06PM L30.00014 Instability in extensional microflow of aqueous gel[1] , ROBERT BRYCE, Department of Physics, University of Alberta, Edmonton, Canada T6G 2G7, MARK FREEMAN, Department of Physics, University of Alberta, Edmonton, Canada T6G 2G7; Institute for Nanotechnology, Edmonton, Canada T6G 2M9 — Microfluidic devices are typically characterized by laminar flows, often leading to diffusion limited mixing. Recently it has been demonstrated that the addition of polymer to fluids can lead to elastic instabilities and, under some conditions, turbulence at arbitrarily low Reynolds numbers in mechanically driven flows [1]. We investigated electroosmotic driven extensional flow of an aqueous polymer gel. Microchannels with 100 micron width and 20 micron depth with the characteristic "D" chemical etch cross section were formed in glass. A Y-channel geometry with two input channels and a single output created extensional flow at the channel intersection. Instabilities where observed in the extensional region by fluorescently tagging one input stream. Instabilities were characterized by 1/f spectra in laser induced fluorescent brightness profiles. Due to the simple geometry of extensional flow and the importance of electroosmotic flows for integrated applications and in scaling, this is of interest for device applications. [1] A. Groisman and V. Steinberg, Nature 405, 53-55, 2000.

[1]This work is supported by NSERC, iCORE, and NRC.

5:18PM L30.00015 Interactions between micro droplets and a flowing soap film , ILDOO KIM, XIAO-LUN WU, University of Pittsburgh — When a jet of micron sized water droplets impact on a thin freely suspended soap film, craters of various sizes are created in the film. Depending on the velocity of the jet and the thickness of the film, a fraction of the particles is able to penetrate through the film without breaking it while others merge with the film. The statistical nature of penetration suggests that the energy barrier for passage is a fluctuating quantity but the cause of such fluctuation is not understood. Using a high-speed video camera, the interaction between the droplet and the film is investigated for various conditions. Aside from its fundamental interest, the technique is potentially useful for generating predetermined number of vortices in the fluid and for depositing precisely passive scalar quantities, such as dyes, into two-dimensional turbulence in the flowing film.

Wednesday, March 7, 2007 8:00AM - 11:00AM –
Session N5 DFD: The Generation of Magnetic Fields in the Cosmos and the Role of Turbulence
Colorado Convention Center Korbel 1A-1B

8:00AM N5.00001 Laboratory models of the Earth's outer core[1] , DANIEL LATHROP, University of Maryland — We construct liquid sodium experiments as models of the Earth's core. Key to understanding these several experimental devices is knowing how turbulence is effected by rotation and magnetic fields. In the approach to the planetary regeme, several remarkable behaviors appear [1]. As rotation and magnetic fields add some measure of elasticity to the flows, several types of driven planetary modes are observed depending on the force balances involved. Ordering the Coriolis, Lorentz, and inertial forces is key to understanding the complicated states observed. While these experiments are undertaken in part to understand the geodynamo, they have led to a number of different first observations, including the magneto-rotational instability [2] and inertial waves in spherical Couette flow. These different approaches to using laboratory experiments are opening up a new direction to understanding the dynamics of the Earth's outer core, other Planetary interiors, and a host of astrophysical objects. [1] W.L. Shew and D.P. Lathrop, "Liquid sodium model of geophysical core convection," Phys. Earth and Planetary Interiors, 153, 136-149 (2005). [2] D.R. Sisan, N. Mujica, W.A. Tillotson, Y.-M. Huang, W.Dorland, A.B. Hassam, T.M. Antonsen, and D.P. Lathrop, "Experimental Observation and Characterization of the Magnetorotational Instability," Phys. Rev. Lett. 93, 114502 (2004).

[1]Funding from the National Science Foundation is greatfully acknowledged

8:36AM N5.00002 Making Magnetic Fields on Cosmic Scales , STEVE COWLEY, University of California, Los Angeles, Department of Physics and Astronomy — Magnetic fields are observed very early in the evolution of structure of the universe. It is not known how or when these fields were created. I will discuss the various theories of the field origin and the fluid mechanical issues that arise. Small scale fields of observable amplitudes are relatively easy to create on short time-scales by turbulent flows or compact objects. The central issue is the the creation of the observed long scale coherence in the field.

9:12AM N5.00003 Generation of magnetic field by dynamo action in a turbulent flow of liquid sodium , JEAN-FRANCOIS PINTON, Ecole Normale Superieure de Lyon — Industrial dynamos routinely generate currents and magnetic fields from mechanical motions. In these devices, pioneered by Siemens, the path of the electrical currents and the geometry of the rotors are completely prescribed. As it cannot be the case for planets and stars, experiments aimed at studying dynamos in the laboratory have evolved towards relaxing these constraints. Solid rotor experiments showed that a dynamo state could be reached with prescribed motions but currents free to self-organize. A landmark was reached in 2000, when the experiments in Riga and Karlsruhe showed that fluid dynamos could be generated by organizing favourable sodium flows, the electrical currents being again free to self-organize. For these experiments, the self-sustained dynamo fields had simple time dynamics (a steady field in Karlsruhe and an oscillatory field in Riga). No further dynamical regimes where reached. We report the observation of dynamo action in swirling flows for which turbulence is fully developed. The flows are generated in the gap between counter-rotating impellers (the von Karman Sodium experiment -VKS). Dynamo action is reached at magnetic Reynolds number Rm≈30. When the impellers are rotating at equal rates, the dynamo field is statistically steady, although the rms fluctuation level is of the order of the mean amplitude. For impellers rotated at different speeds, a variety of dynamical regimes are observed, including magnetic field reversals. We will describe and discuss the features of these dynamos, including the nature of the bifuraction, the scaling of the self-sustained fields, the excess mechanical power, etc. Some regimes have geomorphic characteristics, while others may be relevant in the astrophysical context.

9:48AM N5.00004 Dynamo action in penetrative Boussinesq convection[1] , NICHOLAS BRUMMELL, University of California, Santa Cruz — Dynamo action in any highly turbulent, electrically-conducting fluid medium is plausible. Dynamo amplification of the magnetic fields on the scales of the velocity patterns might be expected if the effects of diffusion and packing of fields are not too drastic. An interesting question is whether magnetic fields can be generated on scales *larger* than the velocity scale. We investigate the generation of magnetic fields in a Boussinesq convecting layer, and examine the effects of including a convectively-stable layer of fluid below, of rotation, and of adding a forced shear. We examine the efficiency of the dynamo and the relative production of small-scale and large-scale magnetic fields.

[1]Supported by NASA SEC-TP grant NNG05G124G

10:24AM N5.00005 Scale interactions in MHD turbulence and dynamo action , PABLO MININNI, The University Corporation for Atmospheric Research — In recent years the increase in computing power, as well as the development of subgrid models for magnetohydrodynamic (MHD) turbulence has allowed the study of a numerically almost unexplored territory in MHD flows: the regime of low magnetic Prandtl number (P_M). This regime is of particular importance since several astrophysical and geophysical problems are characterized by $P_M < 1$, as for example in the liquid core of planets such as the Earth, or in the convection zone of stars as the Sun. Liquid metals used in dynamo experiments to generate magnetic fields are also characterized by $P_M < 1$. In this talk we will review some studies of dynamo action and MHD turbulence for $P_M \leq 1$, down to $P_M \sim 5 \times 10^{-3}$. In particular, we will focus on cases where a large scale flow is present and turbulence develops as the result of an instability. Interactions between scales will be discussed, and evidence of non-local interactions involving disparate scales in simulations of MHD turbulence with resolutions up to 1536^3 grid points will be presented. The implications of these results for universality will be briefly discussed.

Wednesday, March 7, 2007 8:00AM - 11:00AM –
Session N30 DFD: Liquid Crystals: Experiments Colorado Convention Center 304

8:00AM N30.00001 Alignment of Liquid Crystals by Nano- and Micro -Scale Topographic Patterns Made by Nanoimprint Lithography[1] , YOUNGWOO YI, MICHI NAKATA, ALEXANDER MARTIN, NOEL CLARK, Department of Physics and Liquid Crystal Materials Research Center, University of Colorado, Boulder CO 80309, VAIBHAV KHIRE, CHRISTOPHER BOWMAN, Department of Chemical and Biological Engineering and Liquid Crystal Materials Research Center, University of Colorado, Boulder CO 80309 — Topographic patterns prepared using nanoimprint lithography have great potential in the alignment of liquid crystals (LCs) because their preparation is a parallel and low cost process. Nano- and micro- scale topographic patterns are made by stamping a mold on liquid material, which is then cured by UV light illumination. Such topographically patterned plates are used as one of the window of LC cells. Depolarized transmission light microscopy shows that nematic liquid crystals are aligned uniformly along the lines on the linear patterns and aligned either homeotropically or with bistable planar states in patterns of squares, depending on their scale.

[1]This work is supported by NSF MRSEC Grant DMR0213918.

8:12AM N30.00002 Absence of uniform nematic phase for thin 8CB films, ERGYS SUBASHI, RAFAEL GARCIA, Worcester Polytechnic Institute — Certain thermotropic liquid crystal films exhibit a strange phenomenon in which two different thicknesses coexist side-by-side on solid surfaces. For 5CB these two film thicknesses appear to correspond to two different phases: nematic and isotropic. The coexistence persists for a temperature range which depends on the initial thickness of the film. A similar phenomenon is present in films that have a smecticA phase such as 8CB. For these films just below the nematic to isotropic transition temperature, we observe a coexistence region very similar to that observed previously for 5CB. We also report new experiments which show that for 8CB films on silicon, near the smecticA to nematic transition temperature, there is a coexistence region that is strikingly different from the one observed near the nematic to isotropic transition. Furthermore, there is a new phenomenon for 8CB films thinner than a certain critical thickness d*: as the temperature increases or decreases the film goes from smecticA to isotropic and back with no intermediate uniform nematic phase.

8:24AM N30.00003 Electrically controlled negative refraction in a uniaxial nematic liquid crystal, OLEG D. LAVRENTOVICH, OLEG P. PISHNYAK, Liquid Crystal Institute, Kent State University, Kent, Ohio 44242 — We demonstrate the phenomenon of electrically controlled negative refraction at the interface between an isotropic material and a uniaxial nematic liquid crystal, in which the optic axis makes a large angle (40-60 degrees) with the interface and is switched by a modest (few volts) electric field. Depending on the applied voltage, the refracted beam is either on the opposite side of the interface normal as compared to the incident beam (positive refraction) or on the same side (negative refraction) .

8:36AM N30.00004 Effect of the Functionalization Compound on the Magnetic Nanoparticle – Smectic-A Liquid Crystal Interaction: A Phenomenological Model, LUZ J. MARTINEZ-MIRANDA, University of Maryland, LYNN K. KURIHARA, Naval Research Laboratory — We present the details of a phenomenological model that explains how the functionalization or surface compound affects the way that a magnetic nanoparticle interacts with a liquid crystal molecule. This model considers the surface interaction between the functionalization compound and the liquid crystal, and the relative size of the liquid crystal compared to the size of the nanoparticle. These two properties can aid or hinder in the effects of the nanoparticle on the orientation of the liquid crystal, specifically on the magnetic field effects of the nanoparticle in the reorientation of the liquid crystal. Comparisons with experimental data will be presented.

8:48AM N30.00005 ABSTRACT WITHDRAWN —

9:00AM N30.00006 Broadening the Smectic C* Sub-Phases by Chiral and Achiral Doping, J. KIRCHHOFF, L.S. HIRST, Florida State University — Materials exhibiting the liquid crystal smectic (Sm) C* sub-phases have been a topic of great interest for several years and recent work has shown that by mixing chiral and achiral dopants with these materials it is possible to broaden the SmC* subphases significantly, in particular, the intermediate phases (ferrielectric) which typically have a very narrow temp. range [1]. Mixtures of smectics with chiral or achiral dopants were studied to investigate phase stability in the SmC* sub-phases. As dopant conc. is increased, both phase width and the temp. range over which the transition occurs is broadened. These effects have been measured via calorimetry (DSC), and optical microscopy. Electro-optical characteristics of mixtures as a function of dopant conc. were also studied to investigate the effects of phase and transition broadening on material properties as it is not yet clear what role the addition of chiral dopants will play. By controlling phase widths, we hope to expand the possibilities, through carefully formulated mixtures, of generating commercially interesting materials in these phases.
[1] S. Jaradat et al. J. MATER. CHEM. **16**, 3753, (2006)

9:12AM N30.00007 Use of the chiral smectic A liquid crystal electroclinic effect for sensitive measurement of enantiomeric excess[1], DUONG NGUYEN, LIOR ESHDAT, ARTHUR KLITTNICK, RENFAN SHAO, DAVID WALBA, NOEL CLARK, University of Colorado-Boulder — We present here a procedure which is capable of detecting an enantiomeric excess (ee) as low as 10^{-4}% using the electroclinic effect. The electroclinic effect is a field induced effect on the optic axis of the SmA phase of chiral molecules in which the tilt angle θ is linear with the electric field E. Thus, varying the voltage across a cell with planar alignment of a sample of unknown ee in SmA phase induces varying orientation of the director. This in turn induces varying intensity of a laser beam passing through the sample. The signal from the sensor detecting this beam is fed to a lock-in amplifier for low-noise measurement of the beam's intensity variation, from which we can extract even a small ee of the sample.

[1]Supported by grant from NSF MRSEC #DMR 0213918

9:24AM N30.00008 Topological Defect Structure and Annihilation in High-Polarization Freely Suspended Films, CHENHUI ZHU, APICHART PATTANAPORKRATANA, JOSEPH MACLENNAN, NOEL CLARK, Department of Physics and Liquid Crystal Material Research Center, University of Colorado at Boulder — The texture of freely suspended liquid crystal SmC* films of a high polarization material C7 [4-(3-methyl-2-chloropentanoyloxy)-4'-heptyloxybiphenyl] is studied using polarized light microscopy. In particular, we focus on c-director defects with topological strength –1 found in the chessboard texture. Due to the competition between the elastic energy and the electrostatic energy of polarization splay, the c-director field near the defect core consists of four domains with homogenous orientation of the c-director inside each domain. The boundaries between domains are sharp and the c-director orientation jumps by 90 degrees at each boundary. We will present experimental and theoretical studies of the structure of these polarization-stabilized discontinuities. We will also present studies of the annihilation dynamics of +1 and –1 pairs of defects on this high-P material film and compare them to those on low-P material films. [1] E. Demikhov, Europhys. Lett. **25** (4), 259 (1994). [2] E. Demikhov and H. Stegemeyer, Liq. Cry. **18**, 37 (1995). [3] Ch. Bahr and G. Heppke, Phys. Chem. **91**, 925 (1987). [4] D. R. Link, N. Chattham, J.E. Maclennan, and N.A. Clark, Phys. Rev. E **71**, 021704 (2005). This work is supported by NSF MRSEC Grant DMR0213918.

9:36AM N30.00009 Interactions between Structurally Chiral Islands on Freely-Suspended Smectic C films[1], APICHART PATTANAPORKRATANA, CHEOL PARK , JOSEPH MACLENNAN , NOEL CLARK, Department of Physics and Liquid Crystal Materials Research Center, University of Colorado, Boulder, CO 80309, U.S.A — Islands on a freely-suspended Smectic C film, circular regions of greater thickness than the surrounding film area, have strong tangential boundary conditions of the c-director (the projection of the molecular long axis onto the plane of the film) at their edges. These islands form dipolar structures, with an s = +1 topological defect inside and an s = -1 defect nearby on the background film. Unlike in 2D nematics, the c- director field on Smectic C islands does not have reflection symmetry, and we see both left and right-handed islands on the film. Islands with the same handedness form chain-like structures with topological dipoles pointing in the same direction and along the chain (these have been reported in the literature). Here we describe the interaction between left and right-handed islands, where the topological dipoles point in opposite directions and form a quadrupolar structure. The two - 1 defects are half way between the islands and offset from the line joining them.

[1]This work was supported by NASA Grant NAG-NNC04GA50G and NSF MRSEC Grant No. DMR 0213918.

9:48AM N30.00010 A New Bistable SmA Display Mode[1] , HUI-YU CHEN[2], RENFAN SHAO, Department of Physics and Liquid Crystal Materials Research Center, University of Colorado, Boulder CO 80309, EVA KORBLOVA, DAVID WALBA, 3Department of Chemistry and Biochemistry and Liquid Crystal Materials Research Center, University of Colorado, Boulder CO 80309, WEI LEE, Department of Physics, Chung Yuan Christian University, Taiwan 32023, NOEL A. CLARK, Department of Physics and Liquid Crystal Materials Research Center, University of Colorado, Boulder CO 80309 — In the traditional SmA display, crossed polarizers are absent and one can switch a light transparent state to an opaque light scattering state by using laser addressing or electric addressing. Such displays are bright, but of only moderate contrast ratio. Here, we present a new operation mode for a SmA display using two sets of electrodes, with one to induce homeotropic orientation and the other having an in-plane structure to induce planar orientation. This switching with crossed polarizer and analyzer enables a high contrast, bistable electro-optical effect. This SmA display mode exhibits a high contrast ratio (2500:1) for non-striped ITO pattern cells, prefect bistability, and reasonably fast switching (a few ms). These characteristics may enable potential applications on e-paper.

[1]NSC (Taiwan) Grant No. NSC 95-2917-I-033-003 and NSF MRSEC Grant DMR 02-13918 (USA)
[2]Department of Physics, Chung Yuan Christian University, Taiwan 32023

10:00AM N30.00011 The frequency-dependent electrooptic response of the electroclinic effect in deVries SmA materials , CHRISTOPHER D. JONES, Liquid Crystal Materials Research Center and Dept of Physics, Univ of Colorado, UTE DAWIN, FRANK GIESSELMANN, Liquid Crystal Group, Institute of Physical Chemistry, Univ Stuttgart, NOEL CLARK, LCMRC, University of Colorado, PER RUDQUIST, Microtechnology and Nanoscience (MC2), Chalmers Univ of Technology — It is well established that electroclinic switching in standard SmA* materials relates to a reorientation of the molecules in a plane normal to the layers, and thus there is no corresponding change in birefringence due to reorientation about a cone, as is the case in the SmC* phase. When the electrooptic response is then analyzed via lock-in amplifier, the signal at the driving frequency is strong, while the second harmonic response, is non-existent [1]. Using this method we have investigated deVries materials W530 and TSiKN65, and show that there is a frequency-dependent second order response – implying an electroclinic switching that corresponds to a change in birefringence, suggesting a reorientation of the molecule about a cone. We will present our findings and a model for the type of electroclinic switching that occurs in these two materials. Work supported by NSF MRSEC Grant DMR-0213918 and The Swedish Foundation for Strategic Research 2002/0388. [1] W. Kuczynski, et. al., *Ferroelectics*, 244, [491]/191, (2000)

10:12AM N30.00012 Effect of Polarization on the Interactions of SmC* Islands on Freely-Suspended Films[1] , CHEOL PARK , APICHART PATTANAPORKRATANA, JOSEPH MACLENNAN , NOEL CLARK, Department of Physics and Liquid Crystal Materials Research Center, University of Colorado, Boulder, CO 80309, U.S.A — We generate islands, circular regions of greater thickness than the surrounding film area, on freely-suspended SmC* films by applying air jets to the film. The c-director field (the projection of the molecular long axis onto the plane of the film) is strongly tangential at the edges of the islands, leading to the formation of s = +1 topological defects inside the islands and s = -1 defects nearby on the background film. Islands interact via these topological defects, with a short- range repulsion and a long-range dipolar attraction governing their stability and leading to their organization in chain-like structures with an equilibrium island separation. We use optical tweezers to measure the force between a pair of islands as a function of their separation. As we vary the enantiomeric excess and hence the polarization of the liquid crystal, the force scales as the polarization squared and the shape of the force curve changes. Simulations based on a simple model of film elasticity and polarization explain our experimental results fairly well.

[1]This work was supported by NASA Grant NAG-NNC04GA50G and NSF MRSEC Grant No. DMR 0213918.

10:24AM N30.00013 Combination of separate smectic-C-alpha phases in binary mixtures[1] , ZENGQIANG LIU, BRADLEY MCCOY, University of Minnesota, SUNTAO WANG, RON PINDAK, Brookhaven National Laboratory, WOLFGANG CALIEBE, German Electron Synchrotron, PHILIPPE BAROIS, PAULO FERNANDERS, H.T. NGUYEN, Centre de Recherche Paul Pascal, CNRS, Université Bordeaux France, C.S. HSU, National Chiao Tung University, Taiwan, C.C. HUANG, University of Minnesota — Applying resonant x-ray diffraction, we showed that the two previously considered separate smectic-C_α^* phases were combined into a single phase in a series of binary mixtures. The pitch evolved continuously and smoothly, contradicting a previously successful theoretical model. New phase sequences found in our studies can be explained by a newer model. The comparison indicates long-range interactions exist in the smectics.

[1]Work at the National Synchrotron Light Source was supported by the U.S. Department of Energy. The research was supported in part by the National Science Foundation, Solid State Chemistry Program under Grant No. DMR-0106122.

10:36AM N30.00014 Evidence of Broken Reciprocity in Cholesteric Liquid Crystals , NITHYA VENKATARAMAN, MICHELE MOREIRA, BAHMAN TAHERI, PETER PALFFY-MUHORAY, Liquid Crystal Institute, KSU, LIQUID CRYSTAL INSTITUTE TEAM — Reciprocity of scattering of a plane incident wave is predicated on bounded scattering media with symmetric and linear permittivity, conductivity and permeability. In chiral media, such as cholesteric liquid crystals, the dielectric tensor is asymmetric due the presence of odd powers of the wave vector resulting from nonlocality and broken inversion symmetry. Evidence of non-reciprocity has been found in optically active crystals by Bennet [1] and in stacks of cholesteric and nematic liquid crystal cells [2]. Here we present transmittance and reflectance data for cholesteric cells with different pitches having overlapping but distinct reflection bands. We relate our results to simple analytic descriptions of the materials properties and of propagating modes and assess them in light of the requirements for reciprocity. 1. P.J. Bennett, S. Dhanjal, Yu. P. Svirko and N. I. Zheludev, *Opt. Lett.* **21**, 1955 (1996) 2. J. Hwang; M.H. Song; B. Park; S. Nishimura; T. Toyooka; J.W. Wu; Y. Takanishi; K. Ishikawa; H. Takezoe, *Nat. Mat.* **4**, 383 (2005).

10:48AM N30.00015 Lasing Thresholds of Obliquely Pumped Cholesteric Liquid Crystal Lasers[1] , MICHELE MOREIRA, BAHMAN TAHERI, PETER PALFFY-MUHORAY, Liquid Crystal Institute, KSU, VLADIMIR BELYAKOV, LD Landau Institute for Theoretical Physics — Cholesteric liquid crystals (CLCs) in the helical cholesteric phase are 1D photonic band gap materials. Mirrorless lasing has been achieved in dye doped CLC systems. An area of great interest is the reduction of the lasing threshold for optically pumped CLCs. The effects of sample thickness and dye concentrations have been investigated and optimized for CLC systems [1]. However, the pump beam geometry has remained unchanged in most experiments. Numerical calculations of the DFB lasing threshold as function of the angle of incidence have been recently carried out for helical cholesterics [2]. The results predict that the lasing threshold is reduced at oblique incidence for critical angles, and the minimum threshold occurs at the first critical angle closest to the band edge. We have carried out measurements of the lasing thresholds of a variety of cholesteric samples as function of the angle of incidence. The samples were pumped by both ns and ps sources. We present our experimental results, and compare these with predictions of theory. [1]. W. Cao et al, *Mol. Cryst and Liq. Cryst.*, **429**, 101 (2005). [2] V.A. Belyakov, *Mol. Cryst and Liq. Cryst.*, **453**, 43 (2006).

[1]This work was supported by the NSF under grant DMR 0132611.

Wednesday, March 7, 2007 11:15AM - 2:03PM –
Session P29 DFD: Focus Session: Granular Flows II Colorado Convention Center 303

11:15AM P29.00001 Beyond Navier-Stokes Order Effects in Granular Gases[1] , CHRISTINE HRENYA, University of Colorado — The vast majority of continuum theories for rapid granular flows are based on Navier-Stokes order descriptions (up to first order in spatial gradients). In this effort, a simple system is used to illustrate the presence and impact of higher-order effects in both the Knudsen boundary layer and the domain interior. Specifically, a thermally-driven, zero mean flow system is considered via molecular dynamics (MD) simulations. The Knudsen boundary layer is identified via an abrupt mismatch in the simulation data for heat flux and predictions from Navier-Stokes order theories. When access to heat flux measurements is not available, a rule-of-thumb is established to estimate the thickness of the Knudsen boundary layer based on concentration measurements. The effect of boundary layer thickness on continuum predictions is assessed via MD simulations, and further illustrated via a comparison between predictions and experimental data for a vibro-fluidized bed. Next, the presence of higher-order effects in the domain interior is explored via MD simulations. The system displays a stress anisotropy, which can be traced to Burnett order effects. Furthermore, a surprisingly large mismatch is observed between Navier-Stokes order theory and MD values for the heat flux. Because there are no Burnett-order contributions to the heat flux, the responsible mechanisms appear to be beyond Burnett order.

[1]Engineering and Physical Sciences Research Council (UK) and National Science Foundation (US)

11:51AM P29.00002 Power-law tail of the velocity distribution in granular gases , WENFENG KANG, University of Massachusetts Amherst, ELI BEN-NAIM, Los Alamos National Lab, JON MACHTA, University of Massachusetts Amherst — We use a two-dimensional event-driven molecular dynamics simulation to study the velocity distribution of a granular gas. We implement the high energy injection mechanism described in Ref. [1]. At a small rate γ we boost randomly chosen particles to a high energy. The resulting driven steady state is found to have a power-law high-energy tail in the velocity distribution, f(v) $\sim$ v $^{-\sigma}$. The simulation results for the exponent σ are in good agreement with the theoretical predictions of Ref. [1].

[1] E. Ben-Naim and J. Machta, Phys. Rev. Lett. 94, 138001 (2005).

12:03PM P29.00003 Translations and Rotations are correlated in Granular Gases[1] , ANNETTE ZIPPELIUS, University of Goettingen, NICOLAI BRILLIANTOV, University of Potsdam, THORSTEN POESCHEL, Charite, HU Berlin, TILL KRANZ, University of Goettingen — In a granular gas of rough spheres the axis of rotation is shown to be correlated with the translational velocity of the partciles. The average relative orientation of angular and linear velocities depends on the parameters which characterise the dissipative nature of the collision. We derive a simple theory for these correlations and validate it with numerical simulations for a wide range of normal and tangential restitution.The limit of smooth spheres is shown to be singular: even an arbitrarily small roughness of the particles gives rise to orientational correlations.

[1]We acknowledge support by GIF

12:15PM P29.00004 On the possibility of aeolian dunes on a laboratory scale[1] , MATTHIAS SPERL, Duke University, Physics Dept., R.P. BEHRINGER — Recent progress in modeling aeolian sand dunes in the field has resulted in the prediction of a critical linear length scale below which no shape stable dune can form. Under typical field conditions on earth, this length scale is around 10m or larger. Using small (0.05mm) lightweight (0.2g/cc) particles with a proper surface treatment to reduce cohesion we can demonstrate how the dune problem can be scaled down to a lab-size wind tunnel. We demonstrate (a) different transport properties of the particles upon variation of the wind speed, (b) the growth of a heap, (c) the formation of a crest, and (d) ripples on a smaller scale than the heap.

[1]This work is supported by NSF-DMT0137119, DMS0244492, and DFG SP 714/3-1.

12:27PM P29.00005 Experiments on Washboard Road , STEPHEN MORRIS, University of Toronto, NICOLAS TABERLET, JAMES MCELWAINE, STUART DALZIEL, DAMTP, Cambridge University — Granular surfaces to develop lateral ripples (so-called "washboard" or "corrugated" road) under the action of rolling wheels. Similar ripples are observed on railroad tracks and many other rolling, load bearing surfaces. Our aim was to investigate this instability of the flat road surface from the point of view of driven, dissipative granular dynamics. We report the results of both laboratory experiments and soft-particle direct numerical simulations. The experiment consisted of a rotating table 60 cm in radius with a thick layer of sand forming a roadbed around the circumference. A 6 cm radius hard rubber wheel, with a support stationary in the lab frame, rolled on the sand layer. We varied the speed of the table, the details of the grains and the suspension of the wheel. The ripple pattern appears as small patches of travelling waves which eventually spread to the entire circumference. The ripples drift slowly in the driving direction. Interesting secondary dynamics of the saturated ripples were observed, as well as various ripple creation and destruction events. The wavelength of the ripples can be quantized by the finite circumference of the road. All of these effects are captured qualitatively by 2D soft particle simulations in which a disk rolls over a 2D bed of polydisperse particles in a periodic box.

12:39PM P29.00006 Probing Avalanche Dynamics using Speckle-Visibility Spectroscopy. , ADAM ABATE, HIROAKI KATSURAGI, DOUG DURIAN, University of Pennsylvania, Department of Physics and Astronomy — We apply a new light scattering technique called Speckle-Visibility Spectroscopy to the study of avalanches. By directly relating the rate of change of the scattered speckle pattern to the fluctuation dynamics of the flowing sand particles, we attain a precision of 0.1 mm/s. Running for 35 hours at 58 kHz, we simultaneously observe the microscopic short-time fluctuations of the sand particles and the long time behavior of thousands of avalanche events, and thus report avalanche frequency statistics and average shape. Interestingly, while all avalanches turn on in 0.3 s and in a similar way, there is a wide variation in how avalanches turn off. The fluctuation speed reaches a maximum just after the avalanche begins, it remains constant for a while, and then decays to zero. Power spectra of the full data set show that as avalanches slow the dynamics are self-similar ($\sim$1/f^2) and the normalized variance of different events diverge at the turning off time.

12:51PM P29.00007 Erosion of a granular bed by laminar fluid flow[1] , ASHISH ORPE, Physics Dept., Clark U, ALEX LOBOVSKY, EAPS, MIT, RYAN MOLLOY, ARSHAD KUDROLLI, Physics Dept., Clark U, DANIEL ROTHMAN, EAPS, MIT — Motivated by examples of erosive incision of channels in sand, we investigate the motion of individual grains in a granular bed as a function of fluid flow rate to give us new insight concerning the relationship between hydrodynamic stress and surficial granular flow. A closed channel of rectangular cross section is partially filled with glass beads and a fluid and a constant flux Q is circulated through the channel. The fluid has same refractive index as the glass beads and is illuminated with a laser sheet away from the sidewalls. The bed erodes quadratically in time to a height h_c which depends on Q. The Shields criterion, which is proportional to the ratio of the viscous shear stress and gravitational normal stress, describes the observed $h_c \propto \sqrt{Q}$ when a height offset of approximately half a grain diameter is introduced. The offset can be interpreted as arising due to differences between the flow near a porous boundary and a smooth wall. Introducing this offset in the estimation of the shear stress yields a grain flux q_x in the bed load regime proportional to $(\tau - \tau_c)^2$, where τ is the non-dimensional shear stress, and τ_c corresponds to the Shields criteria.

[1]Supported by DOE grants DE-FG0202ER15367 (Clark), DE-FG02-99ER15004 (MIT), and NSF CTS-0334587 (Clark)

1:03PM P29.00008 Segregation in horizontal rotating cylinders: radial and axial band formation, band traveling and merging studied by Magnetic Resonance Imaging. , THOA NGUYEN, ANDREW SEDERMAN, LYNN GLADDEN, Department of Chemical Engineering, University of Cambridge — Radial and axial segregations are investigated by Magnetic Resonance Imaging (MRI). For the first time, full 3D structures and real-time 2D MRI movies showing the progress of segregation over many hours are reported. Data were acquired with high temporal (74 ms) and in-plane spatial resolutions (1 mm $\times$ 1 mm), giving new insights into the underlying mechanisms. The mixture composition can be quantified throughout segregation. The cylinder to be considered is 48 mm in diameter, up to 50 cm long and filled to 50 – 82% by volume with millet and poppy seeds at a 3:1 ratio. In particular, the effects of filling fraction, cylinder length and rotational speed on segregation are addressed. Radial segregation is found to be driven by both core diffusion and the free surface. The former is dominant in the cylindrical core buried under the avalanche layer in systems over 75% full while the latter is significant at lower filling levels. Axial segregation is characterized by band formation, traveling, and merging. In all cases studied, the formation of poppy-rich bands is observed, after which individual bands start to travel at $\sim$3 μm s^{-1} until they are within $\sim$3 cm of a stationary band. Adjacent bands then merge into a single, enlarged poppy band as millet seeds move out of the merging region.

1:15PM P29.00009 Granular Flow in a Rotating Drum: Dry vs. Submerged Flow , DENIZ ERTAS, HUBERT E. KING, ARNOLD KUSHNICK, FUPING ZHOU, ExxonMobil Research and Engineering, CHRISTOPHER BRISCOE, Levich Institute, City College of New York, PAUL CHAIKIN, New York University — We have experimentally studied granular flows in a cylindrical rotating drum, half-filled with nearly monodisperse spherical glass particles in order to investigate the effect of interstitial fluid on these flows. We have conducted two classes of experiments under otherwise identical conditions: The first with air as interstitial fluid and the second where the empty space in the cylinder was completely filled with water. For varying rotation rates, we used a particle tracking method to measure particle velocities near the side wall as a function of distance from the flow surface and the surface velocity as a function of distance from the side wall. In all cases, the velocity (relative to rigid rotational motion) initially decreases linearly from its surface value, followed by exponential decay, as a function of increasing distance from the surface. At a given rotation angle (i.e. overall flux), subaqueous flows exhibit more dissipation and therefore result in steeper surface slopes, a lower strain rate and deeper flows. The effect of the interstitial fluid weakens as rotation rate is lowered, resulting in the same slope in the limit of no rotation, i.e., angle of repose.

1:27PM P29.00010 Velocity Profiles in a Rotating Drum: The Effects of Cohesion , ROBERT C. BREWSTER, UCLA, LEONARDO E. SILBERT, Southern Illinois University, Carbondale, GARY S. GREST, Sandia National Laboratories, ALEX J. LEVINE, UCLA — The dynamics of granular media in a rotating drum is important in a wide range of applications in industry associated with mixing granular materials. The rotating drum also serves as a standard experimental geometry to observe continuous avalanching in the laboratory. We study the effect of interparticle cohesion on the velocity field of the rotating drum using large scale granular dynamics simulations. Such cohesion is easily introduced in the system by a wetting fluid that forms menisci at interparticle contacts. Previously, we have examined the effect of interparticle cohesion in gravity driven chute flows, and have shown that the cohesion has a dramatic effect on the granular rheology. For strong enough cohesion, these forces generate a coherently moving plug at the free surface. In this talk, we examine the velocity profile in the rotating drum geometry in this plug-flow regime. We compare our results for angle of the pile in the continuous flow regime to the experiments of Nowak et al. [*Nature Physics*, **1** (2005)] and we examine the stress and velocity profile within the pile as well.

1:39PM P29.00011 Stability of Binary Granular Mixtures[1] , ADRIAN SWARTZ, JEREMY OLSON, J. BRYCE KALMBACH, RENA ZIEVE, University of California, Davis — We study stability of a binary granular mixture. The two grain types are spherical ball bearings, and hexagonal shapes created by welding seven of the spheres together. The shapes are confined to a two-dimensional drum, which rotates slowly enough for discrete avalanches to occur. On average homogeneous piles of hexagonal reach a higher angle before an avalanche than homogeneous piles of spheres, by nearly twenty degrees. As the concentration of spheres is increased in a pile of mostly hexagons, the stability angle decreases more than twice as fast as expected by a linear interpolation between the homogeneous values. The spheres also tend to clump in the middle of the drum, and this segregation appears to cause the nonlinearity in angle. This indicates that the central portion of the drum is the most important in triggering avalanches.

[1]Supported by NSF under PHY-0243904

1:51PM P29.00012 Shape and Velocity Profile of the Core in a Radially Segregated Rotating Cylinder of Granular Particles , LORI SANFRATELLO, University of New Mexico, EIICHI FUKUSHIMA, ABQMR — We experimentally investigate a 3D biparticulate system that segregates only radially, with no evidence of axial segregation either at or below the surface even after hours of rotation. We compare the location and shape of the core of smaller particles, as well as the location of the bottom of the flowing layer, at various rotation rates using magnetic resonance imaging (MRI) in a 5mm slice at the axial center of a 3D cylinder. MRI is used because of its ability to non-invasively measure bulk behavior as well as spatially resolve dynamic variables (e.g. velocity, diffusion) at any location within a 1-, 2- or 3D system. We also compare the velocity depth profile of the radially segregated system with that of pure small and pure large particle systems and provide an explanation for the observed differences. These investigations may help clarify not only what is occurring within a radially segregating system of particles, but also which mechanisms influence the development of axial segregation.

Wednesday, March 7, 2007 11:15AM - 12:51PM –

Session P30 DFD: Focus Session: Rheology and Hydrodynamics of Wormlike Micellar Fluids

Colorado Convention Center 304

11:15AM P30.00001 Dynamics of the Shear Banding Instability[1] , PETER OLMSTED, University of Leeds — A variety of complex fluids, such as liquid crystals, polymers, and surfactant solutions (lamellae or cylindrical micelles), are easily perturbed by shear flow and exhibit apparent "phase transitions" and complex nonlinear dynamics. "Shear banding," or separation of material into bands of different apparent viscosities, has been reliably observed in wormlike micelles and many other systems. Despite a general one dimensional (1D) theory that predicts stable bands, recent experiments suggest that the generic situation is dynamic, rather than steady bands. After an overview I will discuss recent calculations that address the possibility of rheo-chaos, and two dimensional calculations to verify or refute the previously found 1D solutions. I will also discuss the possibility of shear banding in the closely related system of entangled polymer solutions.

[1]Work done in collaboration with SM Fielding (Manchester University).

11:51AM P30.00002 Light-Induced Gelling in a Micellar Fluid Based on a Zwitterionic Surfactant.[1] , RAKESH KUMAR, SRINIVASA RAGHAVAN, University of Maryland — Fluids with photoresponsive rheological properties (i.e. photorheological or PR fluids) can be useful in a range of applications, such as in dampers, sensors, and valves for microfluidic or MEMS devices. Previously, we have demonstrated a cationic surfactant-based PR fluid whose viscosity can be rapidly decreased by UV irradiation. This viscosity decrease was not reversible. Here, we describe a different formulation based on a zwitterionic surfactant that shows a rapid increase in viscosity (gelling) upon exposure to UV radiation. The formulation consists of the zwitterionic surfactant and a photosensitive cinnamic acid derivative. Initially, the viscosity of the fluid is low indicating the presence of small micelles. Upon UV irradiation, the cinnamic acid derivative is photoisomerized from trans to cis. In turn, the small micelles transform into long wormlike micelles, thus increasing the solution viscosity by more than five orders of magnitude. Small angle neutron scattering (SANS) data confirms the dramatic increase in micelle length. Possible reasons for such changes in micelle dimensions will be discussed.

[1]Light-Induced Gelling in a Micellar Fluid Based on a Zwitterionic Surfactant

12:03PM P30.00003 PB-PEO wormlike micelles under oscillatory shear flow as probed by Time-resolved SANS , MINNE PAUL LETTINGA, BARBARA LONETTI, JOERG STELLBRINK, Forschungszentrum Juelich, JOACHIM KOHLBRECHER, Paul Scherrer Institut, Villigen — Polybutadiene-poly(ethylene oxide) (2.5 kd:2.5 kd) diblock copolymers form wormlike micelles, known to undergo an isotropic to nematic phase transition at 5% w/w. The rheological properties of this system display similarities to surfactant wormlike micelles. The theory describing this type of 'living' polymers uses the concept of reptation in combination with the kinetics of breaking and re-formation of the micelles to predict the dynamical response of such systems. In practice the dynamical characterization is limited to the determination of the crossover point between the storage and lost moduli and thus to the linear properties of the system. Here we present an *in situ* study of the response of pb-peo in the vicinity of the I-N transition to an oscillatory shear field. We determine the (non-) linear response of the Kuhn-segments applying a novel approach to obtain high time-resolution Small Angle Neutron Scattering ($\Delta t \geq 5$ ms). We interpret our data using the reptation time as determined by high-speed confocal microscopy on labeled pb-peo. Thus we obtain a microscopic understanding of the dynamics of 'living' polymers.

12:15PM P30.00004 A rheological study of wormlike micelles flows in microchannel , JEAN-BAPTISTE SALMON, CHLOÉ MASSELON, ANNIE COLIN, LOF, CNRS-Rhodia-Bordeaux 1 — Complex fluids show non linear properties under simple shear flow leading to flow induced phase transitions and instabilities. The flow curve of wormlike micelles exhibit a stress plateau separating high and low viscosity branches, corresponding to shear-banding flows. Our aim is to understand the structure/concentration/flow coupling of wormlike micelles. A microfluidic chip is easy to couple with many analytical methods; it is hence well adapted to our study. We both perform particle image velocimetry and microscopy on a microfluidic chip consisting in channels with dimensions 250 μm large and 1 mm deep. Such a canyon geometry enables us to relate the measured velocity profiles to the local rheology. We evidence shear banding and slip at the walls. Strikingly there is no single rheological law that describes the velocity profiles at different pressure drops. Using microscopy, we point out turbid bands at the walls corresponding to the highly sheared bands. At low pressure drops, these bands are stable in time and their widths increase with increasing pressure until a limit where they fluctuate in space and time.

12:27PM P30.00005 Nonlinear microrheology of wormlike micelle solutions using ferromagnetic nanowire probes[1] , N. CAPPALLO, C. LAPOINTE, D. H. REICH, R. L. LEHENY, Johns Hopkins University — We describe the application of high-aspect-ratio ferromagnetic nanowires to the microrheology of wormlike micelle solutions composed of equimolar cetylpyridinium chloride/sodium salicylate (CPCl/NaSal). Employing video microscopy to track the rotation of suspended nanowires in response to external magnetic fields, we access both the linear and nonlinear rheology of the fluid. The linear viscosity at low rotation rates is strongly temperature dependent as expected from macroscopic rheometry. At high rotation rates the viscosity exhibits pronounced shear thinning. The onset of the nonlinear response is characterized by a temperature-dependent shear thickening that has no apparent counterpart in the macroscopic rheometry. Time-resolved measurements involving step changes in rotation rate reveal that, once the fluid has been prepared into a shear-induced state, it exhibits nonlinear viscosity within the expected linear regime. Further, the shear-induced state of the fluid generates an out-of-plane torque on the wire that we have characterized by time-resolved studies.

[1]Supported by NSF Grant No. DMR-0520491

12:39PM P30.00006 Disentanglement behavior of DNA and wormlike micellar solutions as probed with particle-tracking velocimetry. , POUYAN BOUKANY, SHI-QING WANG, University of Akron — We study an ideal entanglement network to test a number of emerging ideas about how topological entanglement reorganizes in presence of shear flow. Aqueous DNA solutions and wormlike micellar solutions can be highly entangled at very low concentrations and thus very soft yet sluggish. A particle tracking velocimetric method, which was developed recently in our lab [1], was applied to determine the velocity profile of these solutions in simple shear under several flow conditions including large step strain, large amplitude oscillatory shear, startup continuous shear and creep. It is shown [2] that all of the nonlinear viscoelastic flow behavior is associated with development of inhomogeneous shear when nucleation of chain disentanglement takes place in reaction to imposed shear deformation. [1] *Phys. Rev. Lett.* **96**, 016001 (2006); *ibid.* **96**, 196001; *ibid.* **97**, 187801. [2] Manuscripts to be submitted to *Macromolecules* and *Langmuir.*

Wednesday, March 7, 2007 2:30PM - 4:54PM –

Session S29 DFD: Glassy Dynamics and Jamming II Colorado Convention Center 303

2:30PM S29.00001 Correlations of spatial structure and particle motion in shear-induced clusters of a near-glassy colloidal suspension. , DENIS SEMWOGERERE, DANDAN CHEN, ERIC R. WEEKS, Emory University — We study fast-moving particle clusters formed as a result of shear applied to a colloidal suspension near the glass transition. The suspension is of micron-sized PMMA spheres in an index-matched fluid that allows visualization of the individual particles using high-speed confocal microscopy. The particles are tracked and their individual 3D trajectories determined. The shear-induced non-affine motion of each particle is extracted from its trajectory by subtracting the macroscopically imposed shear motion. Fast-moving particles are observed to move cooperatively as a group. We examine correlations between local spatial structure and the non-affine motion of the particles.

2:42PM S29.00002 Shear-driven dynamic clusters in a colloidal glass , CHRISTOPH EISENMANN, CHANJOONG KIM, JOHAN MATTSSON, DAVID WEITZ, DEAS, Harvard University, EXPERIMENTAL SOFT CONDENSED MATTER TEAM — We investigate the effect of shear applied to a colloidal glass on a microscopic level using a shear device that can be mounted on top of a confocal microscope. We find that the glass yields at a critical strain of about 10%, independently of the shear rate. Surprisingly, the yielding is accompanied by an increase of cooperative particle movements and a formation of dynamic clusters which is in contrast to the normal glass transition where one typically finds heterogeneity increasing whilst moving towards the glass transition.

2:54PM S29.00003 Reversibility and self-organization in non-Brownian suspensions[1] , LAURENT CORTÉ, PAUL CHAIKIN, NYU, JERRY GOLLUB, Haverford College, DAVID PINE, NYU — Many-body systems often exhibit irreversible behavior even though the governing equations of motion are reversible. Nevertheless, it is unusual to encounter a physical system in which the transition from reversible to irreversible behavior can be explored experimentally. Recent experiments in our lab on periodically sheared non-Brownian suspensions show a sharp transition from reversible to irreversible chaotic behavior above a concentration-dependent threshold strain amplitude.[2] The observation of a sharp threshold is puzzling as the initial distribution of particles is random, with no obvious length scale for the onset of irreversibility. We develop a simple model, explored through simulation and mean field theory, that captures the salient behavior of the experiments. For small strain amplitude, the model reveals that random displacements of colliding particles can cause the system to self-organize into a reversible state that avoid further collisions. The model provides new insights into how microstructure can spontaneously develop and how random encounters can help a system evolve towards a stable fixed point.

[1]LC supported by Ministère des Affaires Etrangères (France)

[2]D. J. Pine, J. P. Gollub, J. F. Brady & A.M. Leshansky, Nature, **438**, 997-1000 (2005).

3:06PM S29.00004 Ultraslow relaxation in aqueous glucose solutions near the glass transition , DAVID SIDEBOTTOM, Creighton University — We report the results of both a dynamic and static light scattering study of the viscoelastic relaxation of aqueous glucose solutions. Photon correlation spectroscopy of samples with varying glucose concentration was conducted in both the polarized and depolarized scattering geometries. In addition to the usual, non-hydrodynamic, non-exponential, wavevector-independent viscoelastic (alpha) relaxation whose relaxation time approaches 100 seconds at the glass transition temperature, an even slower component of structural relaxation is observed. This ultraslow (exponential) relaxation is present only in the polarized scattering geometry and exhibits a relaxation time that varies as nearly the inverse square of the scattering wavevector. Static light scattering on these same solutions indicate the prescence of clusters with a size of order 50 nm. We speculate (1) that these clusters result from hydrogen bonding of water between glucose molecules and (2) that motion of these clusters within the fluid is the source for the ultraslow relaxation mode seen in the dynamic light scattering.

3:18PM S29.00005 Anisotropic spatially heterogeneous dynamics in a model glass-forming binary mixture , GRZEGORZ SZAMEL, Department of Chemistry, Colorado State University, ELIJAH FLENNER, Department of Physics, University of Missouri — We used computer simulations to calculate, for a model binary mixture, a four-point correlation function which measures the spatial correlations of the relaxation of different particles and the corresponding structure factor. We found that these four-point functions are anisotropic. The anisotropy is the strongest for times somewhat longer than the β relaxation time, but it is quite pronounced even for times comparable to the α relaxation time. At the lowest temperatures the four-point structure factor is strongly anisotropic even for the smallest wavevector q accessible in our simulation.

3:30PM S29.00006 Isothermal compressibility effects in glass-forming liquids and polymers , WENJUAN LIU, RALPH COLBY, Penn State University, JANE LIPSON, Dartmouth College — We develop a simple model to account for the effects of density fluctuations in the dynamics of glass-forming liquids and polymers. The magnitude of the density fluctuation of any liquid is proportional to isothermal compressibility. As the isothermal compressibility at the glass transition increases, the (segmental) relaxation time distribution measured by dielectric spectroscopy broadens and the fragility of the glass-former diminishes. Exceptions to these rules are interesting and will be discussed in detail.

3:42PM S29.00007 Localization Transition of the Three-Dimensional Lorentz Model and Continuum Percolation , FELIX HOEFLING, THOMAS FRANOSCH, ERWIN FREY, Ludwig-Maximilians-Universitaet Muenchen — The localization transition and the critical properties of the Lorentz model in three dimensions are investigated by computer simulations. We give a coherent and quantitative explanation of the dynamics in terms of continuum percolation theory, an excellent matching of both the critical density and exponents is obtained. Upon exploiting a dynamic scaling Ansatz employing two divergent length scales we find data collapse for the mean-square displacements and identify the leading-order corrections to scaling. Our data corroborate a hyperscaling relation that connects dynamic and geometric critical exponents. The non-Gaussian parameter is predicted to diverge at the transition. [F. Hoefling, T. Franosch, and E. Frey, Phys. Rev. Lett. 96, 165901 (2006)]

3:54PM S29.00008 Dynamics during a transient gelation process studied by XPCS , ANDREI FLUERASU, European Synchrotron Radiation Facility, Grenoble, ABDELLATIF MOUSSAID, ESRF, ANDREW SCHOFIELD, Physics Department, Univ. Edinburgh, ANDERS MADSEN, ESRF — Photon correlation spectroscopy with partially coherent X-ray beams (XPCS) available at third generation synchrotron sources is an experimental technique that allows the direct measurement of the low frequency microstructural dynamics that are often present in a large class of soft-condensed matter systems. In many such systems and in particular in concentrated disordered systems, at least two distinct relaxation mechanisms can usually be found. The fast(er) ones correspond to the "trapped" motion of individual particles or aggregates in "cages" created by other particles/aggregates. The slow relaxation modes correspond to the structural re-arrangements of the "cages". In this work we report the XPCS study of the structural dynamics associated with the slow collapse of transient gels consisting of mixtures of sterically-stablised polymethylmethacrylate (PMMA) particles and random-coil polystyrene (PS) dispersed in cis-decalin. The intermediate scattering functions change during the process from stretched to compressed exponential decays indicating a jamming of the system in the full aging regime. A complex aging behavior towards the final collapse of the gel is observed and we propose that large scale network deformations trigger an un-jamming process leading to the collapse.

4:06PM S29.00009 Changing the Packing Fraction by Changing the Geometry: A Hyperbolic Approach to Jamming , CARL D. MODES, RANDALL D. KAMIEN, University of Pennsylvania — The jamming transition is an important and active area of current research in condensed matter physics, touching on phenomena from granular matter to supercooled liquids to glasses. Underlying the problem is the need to fully understand the properties of geometrically disordered configurations and their relation to ordered crystalline states, especially in systems where the effect of entropy dominates over that of energy. Of particular interest are systems for which the densities of isostaticity and crystallization are grossly separated, for example, in higher dimensions. In order to probe these systems with the Virial expansion, however, we must require that the onset of isostatic configurations occurs for sufficiently low numbers of simultaneously interacting particles. This leads us to the study of a hard disc fluid on the hyperbolic plane as a function of the curvature.

4:18PM S29.00010 Packing of Tetrahedral and other Dice , PAUL CHAIKIN, Physics, NYU, STACY WANG, Stuyvesant H. S., ALEXANDER JAOSHVILI, Physics, NYU — The densest packing of tetrahedra remains an unsolved problem. Recently J. H. Conway, and S. Torquato[1], presented the densest packing yet found for tetrahedral, a structure which is a modification of packing tetrahedra in an approximation to an icosahedron and then packing the icoshedra. The best packing was under 0.72, considerably less than the (exact) densest sphere packing of 0.7405... We have measured the random packing of tetrahedral dice in different sized spherical and cylindrical containers, and extrapolated the results to obtain the packing fraction in the limit of no boundaries. We have also measured their density toward the center of a spherical container away from the walls. Both measurements are similar to previous studies of ellipsoids. We find that the dice pack to better than 0.75. But the dice have very slightly rounded vertices and edges. While the total volume change due to the rounding is less than 0.03 (and in the direction to make a larger difference between crystal and random packing), it is difficult to approximate the effect of the rounding. We discuss the relative packings and the nature of the inter-di contacts. 1. J. H. Conway, and S. Torquato, PNAS, **103**, 10612-10617, (2006)

4:30PM S29.00011 Elastic heterogeneity of soft random solids, XIAOMING MAO, PAUL M. GOLDBART, University of Illinois at Urbana-Champaign, XIANGJUN XING, Syracuse University, ANNETTE ZIPPELIUS, University of Goettingen — The spatial heterogeneity of amorphous solids, which records the randomness present at the solidification transition, confers heterogeneity on elastic properties. Especially for soft random solids, which have exceptionally small shear modulus due to the large thermal fluctuations in the positions of the particles, this elastic heterogeneity exhibits interesting long-range correlations. We examine elastic heterogeneity in soft random solids via a two-pronged approach [1]. First, we examine a phenomenological elastic free energy, featuring a quenched random kernel, which induces randomness in the residual stress and Lame coefficients. Second, we explore a semi-microscopic model network using replica statistical mechanics. This model has a vulcanization transition, and the associated Goldstone fluctuations characterize shear deformations and can reproduce the phenomenological model. Via this correspondence we infer the statistical properties of the elastic heterogeneity, finding that correlations involving the residual stress are long-ranged and governed by a universal parameter that also gives the mean shear modulus. This statistical characterization allows the construction of the statistics of non-affine deformations in soft random solids. [1] Xiaoming Mao, Paul M. Goldbart, Xiangjun Xing and Annette Zippelius, cond-mat/0610407.

4:42PM S29.00012 The jamming transition and beyond: Density dependence of the relevant length and time scales in a horizontally vibrated granular monolayer, FREDERIC LECHENAULT, OLIVIER DAUCHOT, CEA, INSTABILITY AND TURBULENCE GROUP TEAM — A dense amorphous monolayer of hard disks is horizontally driven by a glass plate oscillating underneath while confined in a fixed rectangular cell. As the packing fraction is decreased, the system exhibits a transition between a totally jammed state in which the pressure is driven by the contact network and a "supercooled" regime in which the kinetic contribution becomes dominant. We characterize the diffusion properties of such packing across the transition. Furthermore, we compute the self- intermediate scattering function $F_s(\tau, \mathbf{k})$ and the so- called dynamical susceptibility $\chi_4(\tau, \mathbf{k})$. First we show that the former scales with the diffusive length. Then we find that the cooperative scale associated to the latter increases as the packing is increased toward the transition and then drops abruptly as a certain critical density ϕ_c is crossed. Finally we uncover a relationship between F_s and χ_4 and discuss its link with a dynamical fluctuation dissipation relation.

Wednesday, March 7, 2007 2:30PM - 5:06PM –

Session S30 DFD: Monolayers, Membranes & Microemulsions Colorado Convention Center 304

2:30PM S30.00001 Structure, Wrinkling, and Reversibility of Langmuir Monolayers of Gold Nanoparticles, BINHUA LIN, DAVID SCHULTZ, U. of Chicago, XIAO-MING LIN, ANL, DONGXU LI, MATI MERON, JEFF GEBHARDT, P. JAMES VICCARO, U. of Chicago — The assembly of nanoparticles into large, two-dimensional structures provides a route for the exploration of collective phenomena among mesoscopic building blocks. We characterize the structure of Langmuir monolayers of dodecanethiol-ligated gold nanoparticles with *in situ* optical microscopy and X-ray scattering. The interparticle spacing increases with thiol concentration and does not depend on surface pressure. The correlation lengths of the Langmuir monolayer crystalline domains are on the order of five to six particle diameters. Further compression of the monolayers causes wrinkling; however, we find that wrinkled monolayers with excess thiol can relax to an unwrinkled state following a reduction of surface pressure. A theoretical model based on van der Waals attraction and tunable steric repulsion is adopted to explain this reversibility.

2:42PM S30.00002 Experimental and theoretical studies of collapsed fatty-acids Langmuir monolayers[1], WEI BU, CHRIS LORENZ, ALEX TRAVESSET, Iowa State University and Ames Lab, DAVID VAKNIN, Ames Lab and Iowa State University, SUSHIL K. SATIJA, NIST Center for Neutron Research, National Institute of Standards and Technology — Long-chain Langmuir monolayers collapse by exploring the third dimension after being compressed beyond the point of densely packed chains. Recent experimental investigations using surface sensitive X-ray and neutron techniques have shown that arachidic acid (AA) monolayers, spread on pure water surfaces, collapse by forming a trilayer structure that exhibits a remarkable degree of crystalline order. Similar experiments of AA spread on $CaCl_2$ solutions show that the collapsed film consists of a mixture of hydrophobic bilayer domains (where hydrocarbon chains are in contact with water) and trilayer domains. Under suitable experimental conditions, monolayer collapse on $CaCl_2$ solution can produce an almost pure bilayer phase. We present atomistic simulations that account for the role of water, ion binding, and hydrocarbon chain conformations to better understand these experimental results.

[1]Work at Ames Lab was supported by DOE OBESC under contract # 4-7405-Eng-82, partially funded from NSF, DMR-0426597.

2:54PM S30.00003 Dynamic spiral patterns in Langmuir monolayers of chiral molecules, LENA LOPATINA, JONATHAN V. SELINGER, Liquid Crystal Institute, Kent State University — Experiments with Langmuir monolayers of chiral molecules on a water surface report a collective propeller-like precession of the molecules due to the evaporation of water [1]. If the molecular orientation is pinned along an edge, the precession leads to a series of stripes along the edge. This pattern formation has been explained by a dynamic equation due to the Lehmann effect [2]. Here, we consider how the patterns change if the monolayer contains vortices, topological defects which pin the molecular orientation. We model an annular ring with a single vortex at its center, and show that the director field forms a spiral centered at the defect, which reverses handedness between the inner and outer boundaries. We also simulate a system with one vortex and one anti-vortex on a lattice, and find that the defects form spirals with opposite handedness. These analytic and computational results are in good agreement with preliminary experiments [3].
[1] Y. Tabe, H. Yokoyama, Nat. Mater. **2**, 806 (2003).
[2] D. Svensek, H. Pleiner, H. R. Brand, Phys. Rev. Lett. **96**, 140601 (2006).
[3] K. A. Suresh, private communication.

3:06PM S30.00004 Effects of topology and curvature on the hydrodynamics of membranes and interfaces, MARK L. HENLE, A.J. LEVINE, Department of Chemistry and Biochemistry, University of California, Los Angeles, RYAN MCGORTY, A.D. DINSMORE, Department of Physics, University of Massachusetts, Amherst — Understanding membrane and interfacial hydrodynamics is vital for a variety of biological systems and technological applications. Within the cell membrane, for example, the diffusion of proteins is essential for cell-cell signaling. For many of these applications, the membrane/interface is spherical. Such a geometry imposes a *global* topological constraint that, for instance, forces the velocity field on an incompressible membrane to have two vortices. In addition, the *local* membrane curvature strongly modifies particulate transport when it is comparable to the Saffman-Delbrück length (the ratio of the membrane viscosity to the viscosity of the surrounding fluid). In this talk, we present both experimental and theoretical results on the motion of extended objects (rods) in spherical membranes. The experiments investigate the motion of colloidal rods trapped on the surface of a water-in-oil droplet decorated with nanoparticles; the analytic theory solves for the rod mobility as well as the flows in the membrane and the surrounding fluids caused by the motion of such rods. We find that the topology of the membrane can indeed have a significant effect on the dynamics of the rod, and that our theoretical description agrees quantitatively with the experimental results.

3:18PM S30.00005 Langmuir-Gibbs Surface Phases and Transitions , BENJAMIN OCKO, Brookhaven National Laboratory, ELI SLOUTSKIN, ZVI SAPIR, LILACH TAMAM, MOSHE DEUTSCH, Bar Ilan University, COLIN BAIN, Durham University — Recent synchrotron x-ray measurements reveal surface ordering transitions in films of medium-length linear hydrocarbons (alkanes), spread on the water surface. Alkanes longer than hexane do not spread on the free surface of water. However, sub-mM concentrations of some anionic surfactants (e.g. CTAB) induce formation of thermodynamically stable alkane monolayers, through a "pseudo-partial wetting" phenomenon[1]. The monolayers, incorporating both water-insoluble alkanes (Langmuir) and water-soluble CTAB molecules (Gibbs) are called Langmuir-Gibbs (LG) films. The films formed by alkanes with $n \leq 17$ exhibit ordering transition upon cooling [2], below which the molecules are normal to the water surface and hexagonally packed, with CTAB molecules randomly mixed inside the quasi-2D crystal. Alkanes with $n > 17$ can not form ordered LG monolayers, due to the repulsion from the $n = 16$ tails of CTAB. This repulsion arises from the two chains' length mismatch. A demixing transition occurs upon ordering, with a pure alkane quasi-2D crystal forming on top of disordered alkyl tails of CTAB molecules. [1] K.M. Wilkinson *et al., Chem. Phys. Phys. Chem.* **6**, 547 (2005). [2] E. Sloutskin, Z. Sapir, L. Tamam, B.M. Ocko, C.D. Bain, and M. Deutsch, *Thin Solid Films*, in press; K.M. Wilkinson, L. Qunfang, and C.D. Bain, *Soft Matter* **2**, 66 (2006).

3:30PM S30.00006 Electrostatics of planar interfaces in salt solution , WILLIAM KUNG, Northwestern University, A.W.C. LAU, Florida Atlantic University, MONICA OLVERA DE LA CRUZ, Northwestern University — We present an exact field-theoretic formulation for a fluctuating, generally asymmetric, salt density in the presence of a charged plate. The non-linear Poisson-Boltzmann equation is obtained as the saddle-point of our field theory action. Focussing on the case of symmetric salts, we systematically compute, in the weak-coupling limit, first-order correction to the free energy density, arising from electrolyte fluctuation, which can be explicitly obtained in closed form. We find that for systems with moderate salt density, fluctuation corrections to the free energy depends sensitively on the salt concentration as well as their charge valency. Further, we find that electrolyte fluctuation leads to a reduced electrostatic repulsion between two point charges when they are close to the plate. We also consider the application to interfaces separating two semi-infinite regions of different dielectric media.

3:42PM S30.00007 Crystallography on Curved Surfaces , VINCENZO VITELLI, University of Pennsylvania, JULIUS LUCKS, DAVID NELSON, Harvard — We present a theoretical and numerical study of the static and dynamical properties that distinguish two dimensional curved crystals from their flat space counterparts. Experimental realizations include block copolymer mono-layers on lithographically patterned substrates and self-assembled colloidal particles on a curved interface. At the heart of our approach lies a simple observation: the packing of interacting spheres constrained to lie on a curved surface is necessarily frustrated even in the absence of defects. As a result, whenever lattice imperfections or topological defects are introduced in the curved crystal they couple to the pre-stress of geometric frustration giving rise to elastic potentials. These geometric potentials are non-local functions of the Gaussian curvature and depend on the position of the defects. They play an important role in stress relaxation dynamics, elastic instabilities and melting.

3:54PM S30.00008 The use of specular reflectivity of neutrons for the investigation of polymeric membranes , GUEDIOURA BOUZID, BENDJABALLAH NOUEDDINE, HAMDI MAAMAR, KERDJOUDJ HACENE — A polymeric thin film membrane 5μm and 0.5μm thickness was prepared in order to study its physical characteristics with the neutron reflectivity method. The membrane is principally made of cellulose acetate (CA) matrix in within we fix the carrier. The neutron reflectivity profiles versus the momentum transfer measurements are done using Nur reflectometer. The vertical neutron reflectometer at Nur Reactor Algeria utilizes a fixed wavelength of 0.47nm and ^{3}He gas detector; neutrons from the radial beam are reflected by one pyrolytic graphite crystals. Maximum thermal flux, after the monochromator, amounts to approximately 4.0*10^4 neutrons/cm^{2}s. The fit of the experimental data was made using the parett32 software program developed at H.M.I. This program computes optical reflectivity; both for neutron and X- ray, using different models based on momentum transfer Q values or fit measured sets of data. Calculations are carried out by the dynamical approach. The information, not only on layers thicknesses, but also on detailed shape of the scattering density profile is obtained. In a second part, the thin film membrane is submerged in an ionic solution of $ZnCl_2$ at 0.1 mole, this investigation revealed a modification of some internal layers of the membrane. Results are presented for the characterization of a membrane.

4:06PM S30.00009 Coexistence of two colloidal crystals at the nematic liquid crystal-air interface[1] , A. NYCH, V. PERGAMENSHCHIK, U. OGNYSTA, B. LEV, V. NAZARENKO, Institute of Physics, Academy of Sciences, Kyiv, Ukraine, M. SKARABOT, I. MUSEVIC, J.Stefan Institute, Ljubljana, Slovenia, O. LAVRENTOVICH, Liquid Crystal Institute, Kent State University, Kent, OH — Glycerol droplets at a nematic liquid crystal - air interface form two different lattices – hexagonal and dense quasihexagonal – which are separated by the energy barrier and can coexist. The director distortions around each droplet form an elastic dipole. The first order transition between the two lattices is driven by a reduction of the dipole-dipole repulsion through reorientation of these dipoles. The elastic-capillary attraction is essential for the both lattices. The effect has a collective origin.

[1]Supported by CRDF UK-P1-2617-KV-04, DMR 0504516, Ukrainian NAS

4:18PM S30.00010 ABSTRACT WITHDRAWN —

4:30PM S30.00011 Nanoparticle-coated liquid-metal droplets: interfacial tension and electron transport across the interface , KAN DU, B. SAMANTA, L. GLOGOWSKI, V. ROTELLO, M. TUOMINEN, T. EMRICK, T. RUSSELL, A. DINSMORE, University of Massachusetts — We form stable droplets of molten metal, investigate their stability, and demonstrate their potential for forming electronic devices. Droplets of liquid Ga, 0.1-100 microns in diameter, are suspended in water and stabilized by Au or Fe_3O_4 nanoparticles. We measure a large reduction of the surface tension of the Ga droplets when nanoparticles assemble at the interface. To investigate electron transport through the Ga-nanoparticle-Ga junction, we deposit coated droplets on substrates with patterned electrodes. We apply a bias voltage to the electrodes and measure the current after evaporation of the solvent. The nonlinear I-V curve shifts with a gate voltage and indicates a transistor is formed in the junction. Improved understanding of the electrical characteristics may allow inexpensive assembly of a large number of functional devices. We acknowledge support from the Center for UMass/Industry Research on Polymers (CUMIRP) and from NSF NIRT program (CTS-0609107).

4:42PM S30.00012 Strong Attractions with Controllable Size between Hydrophilic Inorganic Macroanions and Reversible Supramolecular Formations , MELISSA KISTLER, Dept of Chemistry, Lehigh University, Bethlehem, PA, ANISH BHATT, GUANG LIU, TIANBO LIU — The polyoxometalate (POM) hydrophilic macroionic solutions, offer a direct connection between traditional fields of simple inorganic ions, colloidal suspensions, polyelectrolytes, particularly proteins and DNAs. Many types of POM macroanions are highly soluble, but undergo reversible self-assembly to form uniform, stable, soft, single-layer vesicle-like "blackberry" structures containing >1000 individual POMs in dilute solutions. Blackberry structures represent a new state of soluble inorganic ions. The driving forces of the POM self-assembly are unlike those of surfactant micelles or colloid aggregates. The POM driving forces are most likely counterion-mediated attraction (like-charge attraction). Blackberry size is controlled by the solvent quality, or the charge density of macroions. Blackberry structures may be analogous to virus shell structures formed by capsid proteins. Unexpected phenomena have been observed in the novel POM systems. References: JACS. 2005, 127, 6942; 2003, 125, 312; 2002, 124, 10942. Nature, 2003, 426, 59. J. Clust. Sci, 2006, 17, 427.

4:54PM S30.00013 Imaging the structure of water near hydrophobic solutes , GERARD C. L. WONG, ROBERT H. CORIDAN, GHEE HWEE LAI, NATHAN S. SCHMIDT, Dept. of Physics, Dept. of Materials Science & Engineering, F. Seitz Materials Research Laboratory, University of Illinois, Urbana-Champaign, MICHAEL KRISCH, European Synchrotron Radiation Facility, Grenoble, France, PETER ABBAMONTE, Dept. of Physics, F. Seitz Materials Research Laboratory, University of Illinois, Urbana-Champaign — Theoretical studies of the structure of interfacial water on the surface of hydrophobic solutes show a strong dependence on the radius of the solute itself. At small radii, a hydrogen-bond network is still capable of forming around the solute, generally forbidding association between the solute molecules. At large radii water can no longer form a hydrogen-bond network around the solute molecule, resulting in the "drying" of the surface and a strong attraction between solute molecules. The crossover length between the two regimes is on the order of a nanometer. We will show that it is possible to make movies of water around hydrophobic solutes of varying size by extracting the density propagator from the dynamical structure factor measured via high-resolution inelastic x-ray scattering spectra at 3rd generation synchrotron sources.

Thursday, March 8, 2007 8:00AM - 11:00AM –
Session U29 DFD: Suspensions and Fluid Dynamics Colorado Convention Center 303

8:00AM U29.00001 Wall-induced Particle migration in Dilute Suspensions of Spheres in Creeping Flow[1] , JERZY BLAWZDZIEWICZ, MAURICIO ZURITA-GOTOR, Yale University, ELIGIUSZ WAJNRYB, IPPT, Warsaw, Poland — The effects of confinement on the dynamics of binary encounters between spherical particles in shear flow are studied for a system bounded by a single planar wall or two parallel planar walls under creeping flow conditions. We show that wall proximity gives rise to a new class of binary trajectories resulting in cross-streamline migration of particles. In contrast, in unbounded space spherical particles on open trajectories return to their original streamlines after a binary encounter is completed (with no non-hydrodynamic forces present). The physical origin of the new trajectories is explained in terms of counter-rotation of particle pairs that is driven by the dynamic pressure distribution. The new type of trajectories constitutes the dominant cross-streamline migration mechanism in dilute wall-bounded suspensions. We show that this mechanism is responsible for the unusually large self-diffusivity observed in experiments by Zarraga and Leighton (2002). The effect of the new migration behavior in dilute suspensions is illustrated using a Boltzmann–Monte Carlo simulation technique. We show that apart from the enhanced self-diffusivity, the walls may also cause formation of a layered suspension microstructure in the low-concentration regime.

[1]Supported by NSF grant CTS-0348175

8:12AM U29.00002 Effect of surface roughness on rate-dependent slip in simple fluids.[1] , NIKOLAI PRIEZJEV, Michigan State University, Dept. Mechanical Engineering — The influence of molecular-scale surface roughness on the slip length in a flow of simple fluids is investigated using molecular dynamics simulations. The parabolic fit of the steady state velocity profiles induced by a constant force is used to define the value of interfacial shear rate. At weak wall-fluid interactions, the slip length increases non-linearly with the shear rate provided that the liquid/solid interface forms incommensurable structures. A gradual transition to the linear rate-dependence is observed upon increasing the wall-fluid interaction. Thermal surface roughness is found to affect the slip behavior significantly: for soft walls the slip length weakly depends on the shear rate. With increasing elastic stiffness of the wall, the linear rate-dependence of the slip length is restored again. Periodically and randomly corrugated surfaces strongly suppress both the magnitude and slope of the rate-dependence of the slip length even for weak wall-fluid interactions. A relation to recent slip flow experiments is discussed.

[1]N.V. Priezjev and S.M. Troian, J. Fluid Mech., 554, 25 (2006).

8:24AM U29.00003 Rheology of Deformable Particle Suspensions by Dissipative Particle Dynamics , ANUJ CHAUDHRI, JENNIFER R. LUKES, Department of Mechanical Engineering and Applied Mechanics, University of Pennsylvania, PA 19104 — Understanding the behavior of colloidal suspensions, emulsions, and other complex fluids under shear flow is important in liquid crystal switching, lab-on-chip processing of biological fluids, self-assembly of polymer structures, and other areas of soft matter physics. Various analytical and computational approaches, including Brownian dynamics, dissipative particle dynamics, and Stokesian dynamics, have been applied to study the rheology of *rigid* particle suspensions. Still lacking are methods capable of treating suspensions containing *deformable* particles such as blood cells or macromolecules. Here we present a new, dissipative particle dynamics-based computational method with this capability. This method is used to calculate the shear rate dependence of viscosity for suspensions of deformable particles with varying stiffnesses.

8:36AM U29.00004 Reducing Viscosity of Liquid Suspensions by pulsed electric or magnetic field[1] , R. TAO, Dept. of Physics, Temple Univ. — Viscosity of liquid suspensions is of great importance. Controlling the viscosity is vital in science and engineering. In electrorheological (ER) or magentorheological (MR) fluids, electric or magnetic field is used to increase the viscosity. However, in most cases we need to lower the viscosity. For example, reducing blood's viscosity improves circulation and prevents cardiovascular events. Lowering the viscosity of crude oil is the key to transporting offshore oil via undersea pipelines. Unfortunately, to date there are no effective methods for reducing the viscosity except by changing the temperature. In case that changing temperature is not an option, such as in the above examples, reducing the viscosity becomes formidable. Here we present a theory and experimental results showing that application of a suitable electric or magnetic field pulse can significantly reduce the viscosity of liquid suspensions for several hours with no change of temperature. The field induces dipolar interactions between the suspended particles and forces them to aggregate into large particles. The aggregation changes the rheological properties of the fluids and reduces the effective viscosity. Positive experimental results with MR fluids and crude oil indicate that this method, developed from the basic mechanism of viscosity, is universal and powerful for all liquid suspensions with broad applications.

[1]The work was supported in part by RAND.

8:48AM U29.00005 Microbubbling viscous liquids and suspensions , KETAN PANCHOLI, Department of Materials, Queen Mary, University of London, Mile End Road, London, E1 4NS, UK, MOHAN EDIRISINGHE, Department of Mechanical Engineering, University College of London, Torrington Place, London, WC1E 7JE, UK — Using a T-junction together with a cross flow technique, we have carried out a detailed study on the formation of near-monodisperse microbubbles in liquids with viscosities in the range of 5-950 mPa s. The data collected were analysed in the context of the classical momentum equation for viscous liquid flow to propose an analytical equation correlating dimensionless viscosity ratio (μ_l/μ_g) to the ratio of liquid pressure to gas pressure (P_l/P_g) required to generate bubbles. This equation is useful in predicting P_l/P_g for microbubbling a liquid having a known viscosity. Our experimental results show that in the liquids investigated, the ratio of P_l/P_g, which is a function of dynamic equilibrium of pressure of liquid and gas at the T-junction, is decreasing proportional to dimensionless viscosity ratio. We calculated radial pressure for a given liquid pressure (P_l) to establish that for liquid viscosities ≥ 48.5mPa s the radial velocity of liquid, which is responsible for imposing radial pressure on the gas-jet, dominates the mechanism of microbubble pinch-off. In contrast, in the low viscosity regime (≤ 48.5mPa s), deceleration of the gas stream from the initial velocity is largely the cause of pinch-off of microbubbles. We made ceramic liquid foams using the technique.

9:00AM U29.00006 Non-Newtonian Impact , DENIS BARTOLO, Laboratoire PMMH (CNRS UMR 7636, ESPCI, P6, P7), GREGOIRE NARCY, LPS de l'ENS (CNRS UMR 8550, P6, P7), DANIEL BONN, LPS de l'ENS (CNRS UMR 8550, P6, P7) and Van der Waals-Zeeman institute, Univ. of Amsterdam. — Spray deposition is widely used in industry (spray painting, pesticide spraying...), but is often inefficient due to an unfavourable wetting interaction of the liquid with the surface. Non-Newtonian polymer effects have been suggested to improve the deposition efficiency, but so far the mechanism has remained elusive and controversial. Here we provide the detailed and quantitative mechanism of the action of the polymers, opening the way to use the non-Newtonian properties to control deposition. We study the impact and subsequent retraction of aqueous drops onto a hydrophobic surface for which rebound of the droplets limits deposition. Adding very small amounts of large molecular weight, flexible polymers dramatically slows down the retraction, inhibiting rebound. We show that the polymers generate strong normal stress effects near the moving contact line of the drop; these can be measured in conventional rheology and can be used to quantitatively account for the slowing down of the retraction.

9:12AM U29.00007 Spectra of single bubble sonoluminescence from noble gas mixtures , MOGENS LEVINSEN, Biocomplexity Lab, Niels Bohr Institute, Blegdamsvej 17, Copenhagen, Denmark — In single bubble sonoluminescence a gas bubble trapped by a resonant sound-field emits pulses of light in synchrony with the exciting field. The exact nature of the light emitting processes is, however, not known, and the extent to which internal compressional waves or even shock-waves in the gas affect these processes is still an open question. Simulations suggest that most likely such waves would lead to segregation of species which presumably would have consequences for the intensity and spectrum of the light emitted. We have measured the spectra from single sonoluminescing bubbles seeded with various mixtures of noble gasses. The results are discussed in the light of theoretical expectations.

9:24AM U29.00008 Steady-state structure formation of two-phase flow in porous media.[1] , THOMAS RAMSTAD, ALEX HANSEN, Department of Physics, NTNU, Trondheim, Norway — Transport of fluids in porous media is highly complex and creates remarkable patterns. We study these structures and the physics behind them in numerical models based on real porous sediments. These are embedded in a steady-state environment so that they represent selections of a larger, global system. As the saturation of the phases are changed within our models , we see a process towards creation of fluid clusters that eventually span the whole system and have a distribution that approaches a power law behavior. The critical saturation where this phase transition takes place, is dependent of the ratio between viscous and capillary forces inside the pores. We study these scaling properties and the physics that leads to the cluster behavior.

[1]Supported by the Research Council of Norway

9:36AM U29.00009 Numerical simulation of flow past an oscillating cylinder beneath a free surface , SERPIL KOCABIYIK, OLEG GUBANOV, LARISA MIRONOVA, Memorial University of Newfoundland — A computational study of laminar flow of a viscous incompresible fluid past an oscillating cylinder close to a free surface is performed. The integral form of unsteady two dimensional Navier- Stokes equations is only discretized in the fluid flow region using fixed Eulerian staggered grid. Well-posed boundary conditions are used at the inflow and outflow boundaries. The no- slip boundary conditions are prescribed at the solid boundary. At the free surface boundary conditions are described by neglecting the motion of ambient air. The volume of fluid method is used to track a moving free surface interface. A piecewise- linear interface reconstruction algorithm is used at each time step for determining the position of both the free surface and fluid-body interfaces. The reconstructed free surface is then advected using computed local velocity field based on a geometrical area-preserving volume of fluid advection algorithm. The numerical simulations are conducted at a fixed Reynolds number, $R = 200$, and at displacement amplitude-to-cylinder diameter ratios of $A = 0.25$ and $A = 0.5$ when submergence depth- to-cylinder diameter ratio is 1.25. Previously computed and observed flow fields around submerged cylinders are compared to current numerical results and good agreement is found.

9:48AM U29.00010 ABSTRACT WITHDRAWN –

10:00AM U29.00011 Non-Newtonian behavior of complex plasma fluids , ALEXEI IVLEV, VICTOR STEINBERG, ROMAN KOMPANEETS, GREGOR MORFILL — One of the remarkable aspects of complex plasmas is that although they are intrinsically multiphase systems, the rate of momentum exchange through collisions between the microparticles (grains) can exceed the coupling to the background neutral gas significantly. Therefore complex plasma fluids can act as an essentially single-fluid system. Numerical simulations predict that the shear viscosity of complex plasmas should have strong non-monotonous dependence on the kinetic temperature of grains. We proposed a self-consistent model which allows us to obtain explicit dependence of the viscosity on the velocity shear rate, with well-pronounced shear-thinning and thickening effects. Under certain condition, the stress vs. strain rate dependence becomes N-shaped, suggesting formation of shear bands. We performed a series of experiments in a planar or cylindrical shear flow geometry, similar to the Couette and Poiseuille flows. This allowed us to retrieve the viscosity of complex plasmas, which turned out to be in fairly good agreement with the theory.

10:12AM U29.00012 Magnetic-Force Enhanced Temperature Gradient[1] , JONATHAN FRAINE, WEILI LUO, Department of Physics, University of Central Florida — The temperature gradient was established in a quasi-one dimensional magnetic fluid by controlling the initial heating and cooling rates. Measurements were done to monitor temperature gradient verses time before and after the cooling and heating were stopped in both zero and applied magnetic field. We found that the magnetic field can enhance the temperature gradient across the sample. The theoretical calculation shows that the effect of field on the temperature gradient is attributed to the magnetic body force that depends on the gradient of the susceptibility.

[1]The authors acknowledge support from NSF NIRT and REU grants for this work.

10:24AM U29.00013 Dynamics of the Shock Waves Generated by High-Speed Liquid Jets , KYOUNG-SU IM, SEONG-KYUN CHEONG, JIN WANG, aps/anl, MING-CHIA LAI, Wayne State University, TRR TEAM, WAYNE STATE UNIVERSITY COLLABORATION — Ultra fast x-radiography and a multiphase numerical simulation were used to reveal complete dynamical characteristics of the shock waves generated by supersonic liquid jets. Unlike the conventional shock waves by a rigid body compression, this shock waves generated by highly transient liquid jets are characterized by an immediately expansion after short compression caused by the liquid deformation due to aerodynamic drag on the jet front. A transition mechanism from the transonic to the supersonic has been clearly analyzed. With the quantitative analysis and the numerical simulation, the dynamic behavior induced by the compression and decompression in ambient gas in the vicinity of the shock front has been examined, and also we demonstrated the dependence of the shock characteristics on spray angles. Under specific injection condition, we provided the detailed internal structures and interacting mechanisms between the ambient gas and liquid spray jet by simultaneously simulating the fluid parameters such as gas velocities, density contours, and liquid sprays.

10:36AM U29.00014 Optical tweezer based study of the motion of a sphere in an oscillatory boundary layer , SHANKAR GHOSH, PRERNA SHARMA, SHOBO BHATTACHARYA, TIFR, Mumbai, India, CONDENSED MATTER PHYSICS AND MATERIALS SCIENCE, TATA INSTITUTE OF FUNDAMENTAL RESEARCH TEAM — Drag forces on a single polystyrene sphere in the vicinity of an oscillatory plate have been measured using an optical tweezer. The phase of the sphere is found to be a sensitive probe of the dynamics. The evolution of the phase from an inertia-coupled regime to a velocity-coupled regime is explored. The frequency dependence of the response is found to be characteristic of a damped oscillator with an effective inertia which is orders of magnitude greater than that of the bare sphere.

10:48AM U29.00015 Dynamics of electrorhoelogical(ER) fluids , JIANWEI ZHANG, Department of Physics, Hong Kong University of Science and Technology, Hong Kong, China, CHUN LIU, Department of Mathematics, Penn State University, University Park, PA, USA, PING SHENG, Department of Physics, Hong Kong University of Science and Technology, Hong Kong, China — Electrorhoelogical (ER) fluids are a class of colloids whose rheological characteristics can be controlled by applying an external electric field. Most applications of ER fluid are determined by its dynamic properties, reflecting the competition between the kinetic energy and internal energies. The relevant physics of dynamic processes is very different from that in static situations. We derive the fully coupled hydrodynamic system modeling the ER fluid dynamics using the energetic variational approach. The interaction between particles is treated as dipole-dipole in character, with a repulsive core. The solid particles and carrier fluid are treated as a two-component incompressible material. The induced electrical polarization and local fields are obtained self- consistently. The forces on the particles and the fluid are derived from the coupling between the transport of the particles and the induced stress. The total force on the moving boundary in stationary state is calculated via total dissipation inside the ER fluid.

Thursday, March 8, 2007 8:00AM - 9:24AM –
Session U30 DFD: Focus Session: Fluid Dynamics of Animal Motion Colorado Convention Center 304

8:00AM U30.00001 Fluid dynamics of animal motion , MICHAEL SHELLEY, Courant Institute of Mathematical Sciences, New York University — No abstract available.

8:36AM U30.00002 ABSTRACT WITHDRAWN –

8:48AM U30.00003 Swimming in a viscoelastic fluid , ERIC LAUGA, MIT — The fluid mechanics of swimming microorganisms was pioneered by G.I. Taylor more than fifty years ago, and is one of the most mature branch of biophysics. Most previous studies have assumed the fluid to be Newtonian. However, a variety of biologically relevant situations involve non-Newtonian fluids, including sperm motion in cervical mucus as well as ciliary transport of mucus in the lungs. In this talk, we present simple models of swimming in viscoelastic fluids and discuss the impact of elastic stresses on swimming kinematics and energetics.

9:00AM U30.00004 A Model for the Viscous Synchronization of Bacterial Flagella , QIAN BIAN, LEILA SETAYESHGAR, THOMAS R. POWERS, KENNETH BREUER, Brown University — Many flagellated bacteria propel themselves by rotating several helical flagella. The motors that rotate these filaments operate in a constant torque mode, and can alternate between counter-clockwise and clockwise motion. Although they reverse direction independently and randomly, the filaments are observed to coordinate and form a bundle during the run phase of the cell motion. We bring both experimental and theoretical tools to study a model problem which considers rotating paddles rather than helical filaments. The paddles are simpler both to construct and to model, and exhibit stronger viscous interactions than thin helices. Experimentally, we find that the paddles coordinate in about 15 rotations, and stay in synchronized motion with a phase difference of $\pi/2$, although this phase difference increases if there is a torque mismatch between the two motors. The synchronization is observed to persist indefinitely. However, as the paddle separation increases, the synchronization is weaker, and can exhibit instabilities. Theoretical models based on the long-range hydrodynamic interaction of Stokes flow are compared with the experimental results.

9:12AM U30.00005 The mechanics of slithering , DAVID HU, Courant Institute, JOHN BUSH, MIT, MICHAEL SHELLEY, Courant Institute — Snakes propel themselves over land using a variety of techniques, including a unidirectional accordion-like mode, lateral sinuous slithering and sidewinding. We explore these friction-based propulsion mechanisms through a combined experimental and theoretical investigation. Particular attention is given to classifying the gaits of snakes according to Froude number and the relative magnitudes of the frictional forces in the tangential and normal directions. While the term "gait" is usually used to describe a sequence of foot movements, here it refers to a sequence of undulations made by the limbless snake. In a simple mass-spring model, we prescribe the muscle activity of the snake and then calculate its motion as required by the torque and force balances on its body. A key feature of our model is that it allows us to rationalize the mode of locomotion of the snake on the basis of propulsive efficiency.

Thursday, March 8, 2007 11:15AM - 2:15PM –
Session V29 DFD: Foams and Emulsions Colorado Convention Center 303

11:15AM V29.00001 Coarsening in steady-state aqueous foam[1] , KLEBERT FEITOSA, DOUGLAS J. DURIAN, University of Pennsylvania — We perform an experiment with a column of aqueous foam maintained in steady-state by a constant gas flow rate at the bottom. In steady-state we measure the bubble velocity u, bubble radius R_{32} and liquid fraction ε in the foam as a function of height. Away from the bottom, capillary effects are negligible and the liquid fraction profile, set by the balance of viscous forces and gravity, does not change with time. Taking the liquid fraction as a given, the gas transport is investigated. We find that the bubbles rise with constant speed equals to the measured gas flux and coarsen as a function of height. We measure the coarsening rate for almost three decades in liquid fraction combining data from steady-state and free drainage experiments. The results show that the coarsening rate grows without bound proportional to $1/\sqrt{\varepsilon}$ for the entire range of liquid fractions.

[1]NASA Microgravity Fluid Physics Grant No. NNC04GB61G

11:27AM V29.00002 Polymorphism in Monodisperse Foams , OLIVIA L. HALT, RANDALL D. KAMIEN, University of Pennsylvania — The aging of dry foams combines the local requirements of Plateau's rules and surface to volume relations with the global requirement of volume conservation. In a wet foam, the size of each spherical bubble is directly related to its radius of curvature, R. For dry foams, however, we must instead consider the mean curvature, H, which controls gas diffusion but is not directly related to the bubble size. Using a mean-field approach, our model connects distributions of mean curvature to distributions of cell size. This conversion makes use of mean field bubbles [1,2]. By considering the positive and negative curvature distributions separately, such that the cells have equal surface area, we obtain an average number of faces close to previously measured values. Also, distributions of cell sizes are obtained that are seen in real foam.

[1] Glicksman M., Phil. Mag., 85 (2005) 3.
[2] Hilgenfeldt S., Kraynik A., Reinelt D., and Sullivan J. Europhys. Lett. 67 (2004) 484.

11:39AM V29.00003 Rheology of wet foams of different bubble sizes and surfactant chemistry , STEPHAN KOEHLER, RAENELL SOLLER, Emory — We present a new rheological technique for measuring the mechanical properties of aqueous foams at different liquid volume fractions, and of different surfactant compositions. We also cosider the influence of particulate matter on the rheology. We find that at high shear rates the liquid drainage rates are diminished.

11:51AM V29.00004 Flow of soft glassy materials in confined geometry , JULIE GOYON, ANNIE COLIN, LOF-Univertsité Bordeaux 1, LOF-UNIVERTSITÉ BORDEAUX 1 TEAM — In this work, we address the question of the flow soft glassy materials in confined geometry. A transparent direct concentrated emulsion of micrometric size flows in a microfluidic channel under a constant applied drop of pressure. The continuous phase or the dispersed phase is seeded with some sub-micrometric fluorescent latex beads. Taking successive pictures of the flow and correlating them allows us to get the velocity profile. We use rectangular micro-channels with high ratio aspect. The experimental data are analysed in the framework of the lubrication. On one hand, the shear stress is calculated thanks to the position in the channel and the pressure. On the other hand, the shear rate is obtained thanks to the slope in the velocity profile. We point out that the flow cannot be described using a unique behaviour law. Indeed, it is perturbed by rearrangements events which induce three-dimensional flows. These events occur preferentially in the vicinity of the wall where they modify and increase locally the velocity. A comprehensive study of the statistics of the rearrangements events is presented. The role of the drop of pressure, the liquid fraction of the emulsion, the droplet size of the emulsion and the attractive forces between droplets are studied. .

12:03PM V29.00005 Novel Shear Banding in 2D Foam Probes Soap Film Friction[1] , JAMES GLAZIER, Indiana Univesity, ARIEL BALTER, Indiana University, REBECCA PERRY, Bowdoin College — A flowing 2D foam (a single layer of bubbles between two glass plates), experiences dissipation from two sources: soap flims moving against the glass plates and soap flims moving against each other. We present preliminary results showing how a new type of shear banding helps us study these various drag forces. We experimentally generate a shear band by injecting air part way along a flowing bubble field in a narrow Hele-Shaw cell. The injected air inflates bubbles as they flow by. These bubbles form an independently flowing channel down the middle of the Hele-Shaw cell. The width and velocity of this channel appear to be selected by the system minimizing the total dissipation. We propose a simple model that agrees with the experimental data. Also, numerical simulations using the Cellular Potts Model (CPM) software $CompuCell3D$ appear to faithfully reproduce this shear band phenomenon. Agreement between our expeirment and simulations provide support for CPM methods for studying foam rheology.

[1]NSF REU Program

12:15PM V29.00006 ABSTRACT HAS BEEN MOVED TO A29 —

12:27PM V29.00007 Entropically Driven Colloidal Assembly in Emulsions , KENG-HUI LIN, Institute of Physics, Academia Sinica, Taipei, Taiwan, LIANG-JIE LAI, Dept. of Physics, National Central University, Chungli, Taiwan, HUI CHEN, Dept. of Chemical Engineering, National Central University — Using the techniques developed by Manoharan [1], we encapsulate small numbers of colloidal microspheres and polymers in oil-in-water emulsion droplets, remove the oil and generate colloidal clusters covered with polymers. We observe two types of arrangement in the clusters. The first kind is the same as the type reported in [1] of which the clusters are formed without polymer. The second kind is the same as the structure reported in [2] of which the clusters are formed by binary colloidal microspheres. The polymers we put in the emulsions induce depletion interactions between colloidal particles. We will show that two types of structures are from the interplay between the depletion interactions and surface tension. [1] Manoharan, Elsesser, Pine, *Science* **301**, 483(2003). [2] Cho *et al.* *JACS* **127**, 15968 (2005).

12:39PM V29.00008 Rheology of solid-stabilized emulsions , KOSTA LADAVAC, Schlumberger-Doll Research, RODRIGO GUERRA, Harvard University, PABITRA SEN, Schlumberger-Doll Research, DAVID WEITZ, Harvard University — Concentrated emulsions can possess strong shear rigidity, in spite of being comprised solely of fluids. When stress is applied the drops deform, create additional surface area and are able to store energy. For surfactant-stabilized emulsions this elasticity is driven by surface tension alone. In case of sollid- stabilized emulsions, where droplets are protected by colloidal particles adsorbed at the interfaces, organization of particles and their rigidity leads to a different response to deformation. We study this packing of a packing – the interplay between 3D structure of emulsion droplets and 2D structure of colloidal particles at their interfaces.

12:51PM V29.00009 Flow of colloidal gels through constrictions , JACINTA CONRAD, JENNIFER LEWIS, University of Illinois at Urbana-Champaign — We use confocal microscopy to investigate the flow behavior of colloidal gels through constrictions of varying geometry. We flow suspensions of attractive silica colloids through microchannels containing a single constriction point. As the colloid volume fraction is increased, the colloids in the microchannels jam and form a clog. Here we investigate the flow properties and the clogging as a function of applied pressure, microchannel geometry, and the colloid volume fraction.

1:03PM V29.00010 Non-affine bubble motion in a two-dimensional, linearly sheared foam , MATTHIAS MOBIUS, GIJS KATGERT, MARTIN VAN HECKE, Leiden University — Two-dimensional foams are an excellent model system to study the non-affine deformations of a disordered, jammed medium under shear. In our experiment we apply linear shear to a monolayer of bubbles that is confined between a soap solution and a glass plate. Through video imaging we track the motion of individual bubbles. We characterize the non-affine motion by looking at the distribution of relative displacement angles, α, of neighboring bubbles [1]. A peak at 90 degrees emerges, which corresponds to bubbles sliding past each other. We investigate the change of the probability distribution of this angle, $P(\alpha)$, as a function of liquid fraction and shear rate. We discuss $P(\alpha)$ in the context of the jamming transition and show that near the transition the bubble motion is dominated by sliding. Moreover, we look at the relationship between the local velocity fluctuations and the shear rate. [1] W. Ellenbroek et al. , accepted for Phys.Rev.Lett.

1:15PM V29.00011 Thermal conductivity measurements in a 2D Yukawa system[1] , V. NOSENKO, A. IVLEV, S. ZHDANOV, G. MORFILL, Max-Planck-Institute for extraterrestrial Physics, J. GOREE, Univ. of Iowa, A. PIEL, Christian-Albrechts University, Kiel, Germany — Thermal conductivity was measured for a 2D Yukawa system. First, we formed a monolayer suspension of microspheres in a plasma, i.e., a dusty plasma, which is like a colloidal suspension, but with an extremely low volume fraction and a partially-ionized rarefied gas instead of solvent. In the absence of manipulation, the suspension forms a 2D triangular lattice. To melt this lattice and form a liquid, we used a laser-heating method. Two focused laser beams were moved rapidly around in the monolayer. The kinetic temperature of the particles increased with the laser power applied, and above a threshold a melting transition occurred. We used digital video microscopy for direct imaging and particle tracking. The spatial profiles of the particle kinetic temperature were calculated. Using the heat transport equation with an additional term to account for the energy dissipation due to the gas drag, we analyzed the temperature distribution to derive the thermal conductivity.

[1]Work in Iowa supported by DOE and NASA

1:27PM V29.00012 Experimental microrheology of quiescent soap films[1] , VIKRAM PRASAD, ERIC R. WEEKS, Department of Physics, Emory University, Atlanta GA 30322 — A soap film consists of a thin water layer that is separated from two bulk air phases above and below it by surfactant monolayers. Previous experiments (Prasad, Koehler and Weeks, PRL 2006) have shown that the coupling between an interface and an infinite bulk fluid is set by a length scale, the ratio between the interfacial viscosity and the bulk viscosity (of order microns to millimeters). This length scale determines the nature of the flow field in the interface and the adjoining bulk phases. In the case of soap films, the thickness of the water layer is an additional length scale, and therefore the exact nature of the coupling between the thin water layer, the surfactant interface and the bulk air phases is unclear. In order to determine this coupling, we use polystyrene spheres as tracer particles and track their motion in the soap films, using both one-and two-particle microrheology. The experimental results are compared to theory, and the consequences for the hydrodynamics of interfaces are discussed.

[1]NASA Grant No. NAG3-2728

1:39PM V29.00013 Janus particles on colloidosomes (Pickering emulsions) and the role of added surfactant , SHAN JIANG, LIANG HONG, STEVE GRANICK, Department of Materials Science and Engineering, University of Illinois at Urbana-Champaign — We describe systematically the synergy between particle and surfactant in stabilizing colloidosomes. Special attention is given to what determines the inversion between O/W and W/O emulsions, the so-called 'catastrophic phase inversion'. At the onset of the catastrophic phase inversion, we find an exceptional double-emulsion structure. Extending this idea, we find that when the dispersed phase is frozen by lowering the temperature below its solid-liquid phase transition, particles can be locked at the interface and further chemically modified into Janus colloidal particles. This affords an easy way to produce Janus colloidal particles with versatile chemical makeup in large quantity.

1:51PM V29.00014 Observing asphaltene aggregation by NMR spectroscopy and relaxation , YI-QIAO SONG, ANDREW POMERANTZ, KOSTA LADAVAC, PABITRA SEN, Schlumberger-Doll Research — Asphaltenes are a class of molecules commonly found in the oilfield and defined by their simultaneous solubility in toluene and insolubility in hexanes. The aggregation dynamics of asphaltenes is currently poorly understood but presents a serious problem to the oil industry because aggregation can clog flow though pipelines and the oil-bearing rocks. Recently, aggregation dynamics of asphaltenes at very low concentration was measured by nuclear magnetic resonance (NMR) of spin-spin relaxation and diffusion, and fluorescence correlation spectroscopy (FCS). Here, asphaltene aggregation at higher concentrations is observed by monitoring the NMR spectroscopy and longitudinal relaxation times (T1) of the solvent protons. These measurements shed new light on the dynamics of aggregation.

2:03PM V29.00015 Towards a 2D nonperiodic Solid , XIAOCHAO XU, DAVID PINE, Department of Physics and Center for Soft Matter Research, New York University — We report on an experimental study of the two-dimensional phase behavior of colloidal dumbbells (dimers) trapped at a water-oil interface. The dimers are made out of $1.0\,\mu\mathrm{m}$ silica microspheres that are fused together at a point. The water-oil interface is very slightly concave so that the dimers are gently compressed by gravity towards the center of interface. The spheres form a stable dense state after a few days. The pair correlation function of single spheres exhibits order on a length scale of about 10 particle diameters. We report on the translational and orientational order of the dumbbells as a function of particle density.

Thursday, March 8, 2007 11:15AM - 1:51PM – Session V30 DFD: Biologically Inspired Physics Colorado Convention Center 304

11:15AM V30.00001 Investigating gecko setae adhesion using a dual-axis MEMS force sensor[1] , GINEL HILL, DANIEL SOTO, Stanford University, ANNE PEATTIE, ROBERT FULL, University of California, Berkeley, THOMAS KENNY, Stanford University — A dual-axis piezoresistive MEMS force sensor was used to investigate the role of orientation angle on the adhesion of gecko hairs, called setae. Made of keratin with nanoscale features, gecko setae are a spectacular, robust dry adhesive with anisotropic adhesion properties. A wealth of recent research has been devoted to synthetic mimicry of the gecko seta. However, most synthetics do not yet display anisotropic adhesion, which is critical for controllable attachment and release. Previous research using a wire gauge tested the role of the pitch angle between the stalk of natural setae and the substrate and found a dramatic cutoff angle of 30°, above which setae detach from the substrate [1]. The present work details the effect of the "roll" angle on natural setae adhesion. [1] K. Autumn, et al. Nature, 405: 681 (2000).

[1]Supported by a Stanford Graduate Fellowship and NSF Grants DMI-0304209 and ECS-9731293.

11:27AM V30.00002 The venation network in leaves as anticracks?[1] , PEDRO REIS, DENIS VALLET, BENOIT ROMAN, Laboratoire PMMH (UMR 7636 CNRS-ESPCI-P6-P7), MECHPLANT TEAM — Thus far, existing models of venation in leaves are entirely biochemical, involving hormonal diffusive processes. These are, however, unable to capture some crucial structural features of the vascular bundles' network such as the existence of reconnection loops. Couder et. al. [1] have recently highlighted the striking similarities between leaf venation and fracture patterns in drying gels, suggesting that a tensorial mechanism may be at play. It is known that, in the initial stages of the formation of vascular bundles, the promesophyll (leave's *bulk*) is under compression since it grows at a faster rate than the protoderm (leave's *skin*). Hence, to take this analogy further, we introduce the concept of an *anticrack*: a localization of deformation under compressive stresses. We have developed an experimental system to develop and explore this concept as when a solid foam is compressed, either uniaxially or biaxially. We analyze the resulting anticrack networks and relate them to the fracture and venation counterparts. For this purpose we use a high resolution image correlation technique to measure the statistics of the localization zones, structural hierarchy and reconnection loops. [1] Y. Couder, L. Pauchard, C. Allain, M. Adda-Bedia and S. Douady, *Eur. Phys. J. B* **28** 135 (2002).

[1]Funded by the EU's NEST-ADVENTURE project MECHPLANT.

11:39AM V30.00003 Dynamics of macromolecules in confined environments[1] , ARMIN RAHMANISISAN, Boston University, CLAUDIO CASTELNOVO, Oxford University, JEREMY SCHMIT, Brandeis University, CLAUDIO CHAMON, Boston University — The dynamics of a ring macro-molecule confined to a two dimensional cell is studied. A connectivity-preserving kinetically constrained lattice gas model is introduced and used to study the effects of the shrinking of the box on dynamical correlations using Monte-Carlo simulations. It is found that the monomers comprising the macro-molecule manage to diffuse around the box with a mean squared displacement of the order of the square of the box dimensions, even at densities close to the frozen fully-packed configuration where the overall geometry remains almost unchanged over long times. Reptation and fingering events are observed and appropriate correlation functions are introduced to analyze the monomer motion and polymer reshaping at different densities.

[1]NSF-DMR 0403997

11:51AM V30.00004 Piezoelectricity as possible mechanism for mechano-, and magneto-receptions , ANTAL JAKLI, JOHN HARDEN, CODY NOTZ, CHRIS BAILEY, Liquid Crystal Institute, Kent State University — We have studied the piezoelectric responses of 2 dry phospholipids (L-a-Phosphatidylcholine) purchased from Avanti Inc.model membranes. The material was sandwiched between two parallel plates separated by 5μm-60μm distances and aligned with smectic layers mainly parallel to the substrates. The material has a SmA* phase which is similar to the bilayers of cell membranes. Due to its symmetry it should be piezoelectric and may produce electric current normal to the shear plane when one of the substrates is moved with respect to the other one. We have experimentally verified this statement and found the generation of electric polarization up to 300nC/cm^2 when the shear induced a director tilt of about 5 degrees. We have also measured generation of electric current in phospholipids doped with 1% of ferrofluid of Fe_2O_3 nanoparticles when 100G magnetic field was applied periodically on the material. Details of the observations and the relevance of these effects in mechano-, and magneto-receptions will de discussed.

12:03PM V30.00005 Planar Model of Orbital Paramagnetism in B-DNA and A-DNA at Low Temperatures. , MICHAEL J. HARRISON, Michigan State University — We develop a planar model of B-DNA which exhibits orbital paramagnetic properties at low temperatures arising from a small number of conducting pi electrons that move in a parabolic potential attracting them towards the central axis of the model molecule. The paramagnetism is nonlinear in applied field and can have a maximum several times the magnitude of diamagnetism per particle in an extended 2DES. The model is consistent with recent experimental observations [1] provided that only a small number of itinerant pi band electrons of higher energy are assumed to participate, amounting to only 1% of the total number of pi stack electrons from base pairs which are thought to constitute a hybridized core within the actual double helix. The model indicates that the encladding water molecules attached to wet B-DNA provide dielectric screening of the attractive parabolic potential, and can explain the presence of orbital paramagnetism, which is experimentally absent in dry A-DNA [1]. S. Nakamae, et al, PRL 94, 248102, (2005).

12:15PM V30.00006 Electromechanics: An analytic solution for graded biological cell.[1] , KIN LOK CHAN, K. W. YU, The Chinese University of Hong Kong — Electromechanics of graded material has been established recently to study the effective response of inhomogeneous graded spherical particles under an external ac electric field.[1, 2]Such particles having a complex dielectric profile varies along the radius of the particles. The gradation in the colloidal particles is modeled by assuming both the dielectric and conductivity vary along the radius. More precisely, both the dielectric and conductivity function are assumed to be a isotopic linear function dependence on the radius variable r, namely, $\varepsilon(r) = \varepsilon(0) + A_1 r$, $\sigma(r) = \sigma(0) + A_2 r$.In this talk, we will present the exact analytical solutions of the dipole moment of such particle in terms of the hypergeometric functions, and the effective electric response in dilute limit. Moreover, we applied the dielectric dispersion spectral representation (DDSR) to study the Debye Behavior of the cell. Our exact results may be applied to graded biological cell suspensions, as their interior must be inhomogeneous in nature. [1] En-Bo Wei, L. Dong, K. W. Yu, Journal of Applied Physics 99, 054101(2006) [2] L. Dong, Mikko Karttunen, K. W. Yu, Phys. Rev. E, Vol. 72, art. no. 016613 (2005)

[1]This work was supported by RGC Earmarked Grant.

12:27PM V30.00007 TASEP with extended particles and local inhomogeneities[1] , JIAJIA DONG, BEATE SCHMITTMANN, ROYCE K.P. ZIA, Dept. Physics, Virginia Tech — Though much is known about the totally asymmetric simple exclusion process (TASEP), there are still non-trivial characteristics worthy of further exploration. In particular, in TASEPs with extended particles that "cover" $\ell > 1$ lattice sites, non-trivial correlations between the particles exist, even for a case with a trivial distribution for the microscopic configurations. Further, ξ, the characteristic length of these correlations can be extremely long, e.g., $O\left(10^2\right)$. They set up interesting structures in the density profile behind "bottlenecks" (localized inhomogeneities, with hopping rates q smaller than those in the rest of the lattice: $q < 1$) in the system. For TASEPs with open boundaries, we study how one or more such bottlenecks affect both the profiles and the overall current. Using simulations, we present results for a range of q, ℓ, and the *locations* of the inhomogeneities: x_i. For example, the current is somewhat enhanced if a single bottleneck is located close to either system boundary. But it is reduced significantly if two bottlenecks are present and closely spaced, i.e., provided $|x_1 - x_2| \leq \xi$. We also discuss the possible impact of these findings on ribosome queueing and codon optimization in protein production.

[1]NSF DMR-0414122 and NSF DGE-0504196

12:39PM V30.00008 The Real-Time Dose Measurement Scintillating Fiber Array for Brachytherapy Procedures , LAWRENCE TYNES, Hampton University — Brachytherapy is a treatment modality that uses tiny radioactive sources (few mm in length) by delivering enough doses to kill cancer tumors or plaque build-up. The type of sources used in hospitals include both gamma and beta emitters. Presently, the technique suffers from not having a single detector with the capability of providing accurate dose distribution information within sub-mm accuracy. The current standard is based primarily on well chambers and film dosimetry. The Center for Advanced Medical Instrumentation (CAMI) at Hampton University is developing a Scintillating Fiber Based Beta Detector prototype in collaboration with the National Institute for Standards and Technology (NIST) to address this problem. The device is composed of an array of 1x1 **mm**^{2} scintillating fibers optically coupled to photo-multiplier tubes for photon-to-current conversion. A CAMAC LabView based data acquisition system is used for real time data collection and histogramming, data analysis. A set of data were collected at the nearby Bon Secours DePaul Medical Center using a GammaMed 12i HDR after-loader housing a 6.62 mCi Ir-192 source. Preliminary comparison between our device and film dosimetry will be discussed.

12:51PM V30.00009 Modeling Blood Filtration in the Treatment of Septic Shock , GLENN FOSTER, ALFRED HUBLER, Center for Complex Systems Research, University of Illinois at Urbana-Champaign, Department of Physics — Sepsis, the overreaction of the inflammation and coagulation responses to infection, is the leading cause of death in non-coronary intensive care unit patients in the US. Anti-mediator drugs have been generally ineffective, but by considering the network of cytokine interactions, we illustrate how filtering the cytokines in the blood leads to a reduced response. We further illustrate by applying an appropriate filter to existing immune response models as well as discuss both practical and optimal filter parameters.

1:03PM V30.00010 A novel flow cytometry configuration for the detection of magnetic microparticles. , JOHN MARTIN, CHRISTOPHER CARR, ANDREI MATLACHOV, HENRIK SANDIN, MICHELLE ESPY, ROBERT KRAUS, Los Alamos National Laboratory — We have developed a technique for detecting magnetic microparticles in a novel laser-based flow cytometry configuration that incorporates a giant magnetoresistive (GMR) sensor. To achieve the highest possible sensitivity, it is advantageous to minimize the distance from the GMR sensor to the microparticle. Initially, we passed ferromagnetic microparticles (diameter <100 microns) through polymer capillary tubing that passed directly on top of the GMR. While the capillary tubing provides a controlled flow path, it imposes a standoff between the sensor and the microparticle that is never less than 200 microns (due to the tube wall thickness). This standoff limits the range of magnetic microparticles we can detect. Another proposed technique to achieve minimum standoff is to fabricate microfluidic flow channels on top of the GMR itself. We have developed a new approach for minimum standoff, which does not require microfluidics. We will describe this technique, discuss the performance of the commercial GMR sensor and finally report on the detection of magnetic microparticles in this new flow configuration.

1:15PM V30.00011 Computational Phlebology: The Simulation of a Vein Valve , GAVIN BUXTON, NIGEL CLARKE, Durham University — We present a three-dimensional computer simulation of the dynamics of a vein valve. In particular, we couple the solid mechanics of the vein wall and valve leaflets with the fluid dynamics of the blood flow in the valve. Our model captures the unidirectional nature of blood flow in vein valves; blood is allowed to flow proximally back to the heart, while retrograde blood flow is prohibited through the occlusion of the vein by the valve cusps. Furthermore, we investigate the dynamics of the valve opening area and the blood flow rate through the valve, gaining interesting insights into the physics of vein valve operation. It is anticipated that through computer simulations we can help raise our understanding of venous hemodynamics and various forms of venous dysfunction.

1:27PM V30.00012 ABSTRACT WITHDRAWN —

1:39PM V30.00013 Evolution of DNA Compaction in X-Ray Compatible Microflow Foil Devices , SARAH KOESTER, HEATHER M. EVANS, ROLF DOOTZ, Max Planck Institute for Dynamics and Self-organization, Goettingen, Germany, BERND STRUTH, HASYLAB, Hamburg, Germany, THOMAS PFOHL, Max Planck Institute for Dynamics and Self-organization, Goettingen, Germany — Spatially resolved X-ray microdiffraction in hydrodynamic focusing microdevices provides new opportunities to study time-resolved reactions of complex fluids. A demonstration of this technique as applied to the liquid crystal 8CB was recently reported [1]. Here, we discuss the dynamics of the compaction of DNA by polyimine dendrimers, as studied using microfluidic devices. Due to the laminar flow inside the channels a highly defined, diffusion controlled compaction of DNA occurs. Different snapshots in the time of the reaction are accessible at varying spatial positions along the interaction jet. We use newly developed X-ray compatible microflow foils made from PDMS and Kapton and having dimensions ranging from 30 to 150 micrometers. The real-time evolution of a DNA-dendrimer columnar mesophase with an in-plane square symmetry is reported. These studies are also extended to include a larger library of dendrimers whose size and charge approach those of the biological histone proteins. [1] Dootz, Evans, Koester, Pfohl, accepted to Small.

Thursday, March 8, 2007 2:30PM - 5:30PM –

Session W30 DFD: Pattern Formation and Nonlinear Dynamics Colorado Convention Center 304

2:30PM W30.00001 Optically-Induced Spatial Forcing in Rayleigh-Benard Convection[1] , GABRIEL SEIDEN, STEPHAN WEISS, EBERHARD BODENSCHATZ, Max Planck Institute for Dynamics and Self-Organization — Spatial forcing of spatially extended pattern forming systems has received little attention over the past years. Here we report experimental results on optically forced Rayleigh-Benard (isotropic system) and inclined layer convection (anisotropic system). These include a mapping of the phase space as a function of forcing periodicity and forcing strength. A comparison of the observed patterns with the predictions from Ginzburg-Landau theories is made.

[1]This work is supported by the Max Planck Society.

2:42PM W30.00002 Apparatus for Real-Time Acoustic Imaging of Rayleigh-Bènard Convection[1] , KERRY KUEHN, JONATHAN POLFER, JOANNA FURNO, Wisconsin Lutheran College — Shadowgraph visualization of the Rayleigh-Bènard instability in optically transparent fluids has enabled comparison between theoretical and experimental work on a well defined nonlinear system. Rayleigh-Bènard convection in liquid metals, however, remains largely unexplored owing primarily to the difficulty of imaging flow patterns in opaque fluids. We have designed and built an apparatus for high-resolution real-time imaging of convective flow patterns in optically opaque fluids which takes advantage of recent advances in two-dimensional ultrasound transducer array technology. The experimental apparatus employs a modified version of a commercially available two-dimensional ultrasound camera, similar to those now employed in non-destructive testing of solids. Images of convection patterns are generated by observing the lateral variation of the temperature dependent speed of sound *via* refraction of acoustic plane waves passing vertically through the fluid layer. The apparatus has been utilized to observe straight rolls in transparent 5 cSt. silicone oil. Thus far, we have not observed stable convection rolls in liquid mercury.

[1]Supported by NSF grant DMR-0416787 and DOE grant DE-FG02-04ER46166

2:54PM W30.00003 Tension kills ... harmonic moments in viscous fingering , MATTHEW THRASHER, ALEXANDER LESHCHINER, HARRY L. SWINNEY, Center for Nonlinear Dynamics, University of Texas at Austin, MARK B. MINEEV-WEINSTEIN, Los Alamos National Laboratory — We measure the displacement of oil by air between two horizontal, closely-spaced glass plates to track the evolution of harmonic moments, which are integrals of integer powers of $z = x + iy$ over the oil domain. Richardson's theory (1972) predicts that the harmonic moments should be *time invariant in the absence of surface tension*. When we extend the theory to include surface tension, the harmonic moments are predicted to *decay in time because of surface tension*. From measurements of the time decay of the harmonic moments, we obtain a value for the surface tension within 5% of the accepted value. To obtain such precise agreement, the effect of silicone oil wetting the glass plates must be included. Our results implicitly validate Richardson's theory and directly demonstrate that a full description of interface dynamics in terms of harmonic moments is physically realizable and robust. In addition, a novel growth method using feedback produces nearly n-fold symmetric bubbles.

3:06PM W30.00004 The early stages of sidebranching in dendritic crystal growth. , ANDREW DOUGHERTY, THOMAS NUNNALLY, Dept. of Physics, Lafayette College — We report an experimental study of the early stages of sidebranching in the dendritic crystal growth of NH_4Cl crystals in aqueous solution. In steady state, the growing dendrites are characterized by a smooth, nearly parabolic tip. A short distance behind the tip, sidebranches begin to emerge. We characterize the growth of the sidebranches by an envelope $A(z)$, where z is the distance behind the tip. We consider two basic models. In one model, the smooth tip is unstable, and the sidebranches result from the selective amplification of microscopic noise. In this model, $A(z)$ depends on the amplitude of the noise $\bar{S}$ and on various materials parameters. In the second model, the dendrite tip grows in an oscillating mode, with sidebranches emerging like waves in its wake. We have observed no strong oscillations, but very small amplitude ones can not be ruled out. Given the finite experimental resolution, no measurement of the tip region can be completely free of contamination from early sidebranches. We will discuss this and other experimental challenges that need to be overcome before we can understand the origin of sidebranches.

3:18PM W30.00005 Pattern selection in columnar joints , LUCAS GOEHRING, STEPHEN MORRIS, University of Toronto — The pattern of columnar jointing is well known from geological formations such as the Giant's Causeway in N. Ireland, or the Devil's Postpile in California. It arises when a directionally propagating array of cracks arrange themselves into a roughly hexagonal network, which leaves behind a remarkably well ordered collection of prismatic columns. This ordering is efficient, and visually impressive, but not perfect. Experimental observations of columnar jointing in corn starch have shown that, as it matures, the pattern settles down into a well defined, statistically steady state with residual disorder. The same quantifiable amount of disorder can be shown to exist in the pattern of igneous columnar jointing. We report on the dynamics of the mature pattern of columnar jointing, and compare it to models of this phenomenon. In particular, we compare it to an evolution model based on voronoi tessellations, a phase-field model, and a model inspired by 2D foam coarsening.

3:30PM W30.00006 Flowers in the Fourth Dimension , REBECCA THOMPSON-FLAGG, MICHAEL MARDER, University of Texas at Austin — Buckling membranes are seen often in nature from daffodils to torn plastic sheets. These patterns are produced by imposing certain types of metrics on thin sheets. This work looks specifically at patterns formed at the edge of trumpet shaped sheets which are forced to obey an exponentially decreasing metric. Using geometrical techniques a condition for cylindrical symmetry is found. Equations developed by Nash are used to evolve a trumpet from below the limit past the limit. These equations are used to demonstrate that trumpets past this limit cannot fully adopt the metric in three dimensions. A molecular dynamics code is used to create a sheet with points connected by Hookian springs. By changing the equilibrium distance between the springs a target metric can be imposed on the sheet. The energy of the sheet is minimized. The sheet is allowed to move into a fourth spacial dimension and the energy of the sheet in four dimensions, both below and above the symmetry limit, is compared to the minimum energy in three dimensions.

3:42PM W30.00007 Pattern formation in heterogeneous self-oscillating polymer gels. , VICTOR YASHIN, ANNA BALAZS, Department of Chemical Engineering, University of Pittsburgh, Pittsburgh, PA 15261. — The chemical reaction and deformations are inherently coupled in the chemo-responsive polymer gels that participate in the Belousov-Zhabotinsky reaction (BZ gels). Chemical oscillations due to the BZ reaction cause variations in the gel's size and shape because of the hydrating effect of the oxidized metal-ion catalyst linked to the polymer. Physical and chemical patterning of self-oscillating gels would facilitate creating active materials that exhibit desirable spatiotemporal behavior. The heterogeneous self-oscillating gels might be designed to respond to external stimuli by switching between pre-programmed dynamic patterns. We explore these potentialities through modeling 2D dynamics of the structurally heterogeneous BZ gels. We start by considering the effects of a spatially non-uniform crosslink density, volume fraction of polymer, and catalyst distribution on the domain of the oscillatory regime. Then, the propagation of the swelling-deswelling waves through the structurally patterned gels is simulated using the gel lattice-spring model approach. We demonstrate and discuss how the spatial organization of the heterogeneous gel affects the origination and propagation of waves.

3:54PM W30.00008 The effects of pattern morphology on late time scaling in the Cahn-Hilliard model[1] , TIMOTHY SULLIVAN, Kenyon College, Gambier, OH, PETER PALFFY-MUHORAY, Liquid Crystal Institute, Kent State University, Kent, OH — As previously reported, numerical simulations of the dimensionless Cahn-Hilliard equation, have been performed in 2D. The initial state consisted of Gaussian distributed random values on a 540 by 540 grid. The Cahn-Hilliard equation conserves the spatial average of the dimensionless concentration difference, $\langle\psi\rangle$, and initial conditions were chosen with $\langle\psi\rangle$ ranging from 0 to 0.9. As time progresses the system quickly separates into distinct regions where $\langle\psi\rangle \approx +1$ or $\langle\psi\rangle \approx -1$ and then slowly coarsens. Analysis of the late time scaling of a characteristic pattern size scale,$R_G(t)$, the first zero of the pair correlation function, showed that near $\langle\psi\rangle = 0.2$ the time to reach the expected dynamical scaling regime grew very long. This, coupled with the change in the pattern from sinuous structures near $\langle\psi\rangle = 0$ to a pattern of circular regions for larger values of $\langle\psi\rangle$, suggest a morphological phase transition. We explore this idea and will report on our attempts to create order parameters describing the pattern and will present results on the behavior of the candidate order parameters near $\langle\psi\rangle = 0.2$.

[1]Work supported by the Liquid Crystal Institute, the Ohio Supercomputer Center, and NSF grant DMS0440299

4:06PM W30.00009 The onset of activations in the oscillatory Belousov-Zhabotinsky reaction[1] , HAROLD HASTINGS, SABRINA SOBEL, Hofstra University, RICHARD FIELD, The University of Montana — The unstirred, ferroin catalyzed Belousov-Zhabotinsky (BZ) is a prototype chemical system exhibiting traveling waves of oxidation in an oscillatory or excitable medium. A typical thin- layer BZ medium (approx. 2D) displays a red (reduced) induction phase lasting several minutes, followed by "spontaneous" formation of "pacemaker" centers that oscillate between red and blue states and generate target patterns of concentric, outward- moving waves of oxidation (blue) in the red medium. The origin of these pacemaker centers is not yet completely understood. This talk will describe a reduced stochastic model for the origin of pacemaker centers (extending the Oregonator of Field, Koros and Noyes) and recent work of the authors (J. Phys. Chem. A. (Letter); 2006; 110; 5-7), which reproduces experimentally observed oxidation states and nucleation rates.

[1]Partially supported by US NSF grants MRI-0320865 and CHE-0515691.

4:18PM W30.00010 Classical 2d dynamics simulations of metallic spheres in highly viscous medium , PETER FLECK, ALFRED HUBLER, Center for Complex Systems Research, Department of Physics, University of Illinois at Urbana-Champaign — We study the classical dynamics computations of metallic spheres immersed in highly viscous, but weakly conducting medium while exposed to the electro-static field of external electrodes of varying geometries. We represent the system's charge dynamics by the spheres' multipole moments as induced by the electrodes. We theoretically derive the force contributions on an individual sphere including feedback effects, and compare these with results from finite-element computations. We find an individual sphere to oscillate between opposite electrodes only if sufficient charge is retained on the sphere on its path for given material parameters of the medium and distance between the electrodes. We discuss the system's parameter ranges necessary for line arrangements of multiple spheres to emerge. Finally, we compare our computations with an experiment of ballbearings in castor oil.

4:30PM W30.00011 Particle-based model of Min-protein oscillations in *Escherichia coli* , ADAM BERMAN, KERWYN HUANG, NED WINGREEN, Princeton University — In *Escherichia coli* cells, the Min proteins, which are required for division site selection, oscillate from pole to pole via a Turing instability. During these oscillations, two of the Min proteins, MinD and MinE self-associate and co- associate on the bacterial inner membrane forming dynamic structures including a ring of MinE protein, compact polar zones of MinD, and zebra stripes in filamentous cells. Such rich behavior in a system with so few species has made the Min proteins a model system for applying computational methods to study intracellular dynamics in bacteria. Though mean-field computational models successfully reproduce the coarse-grained oscillatory dynamics in both rod-shaped and round *E. coli* cells and also predict that the Min-proteins actively detect cell shape, the mean-field models cannot address questions raised by the recent finding that MinD forms a small number of large polymers on the membrane. First, it is unclear how the intrinsic dynamics of polymer formation, namely polymer nucleation and growth, affect the pole-to-pole oscillations. Second, it is not understood how the oscillations influence the morphology of the MinD polymers. To study this coupling between MinD polymerization and pole-to-pole oscillation, we employ a particle-based computational model. In this talk, we will describe this model, which produces both large polymers and pole-to-pole oscillations.

4:42PM W30.00012 Highly nonlinear dynamics in 1D granular metamaterials: anomalous interaction of solitary waves with interfaces[1] , CHIARA DARAIO, Aeronautics and Applied Physics, Caltech, VITALI F. NESTERENKO, Materials Science and Engineering Program, University of California, San Diego, ERIC B. HERBOLD, Mechanical and Aerospace Engineering Department, University of California, San Diego — One dimensional chains of uniform beads support the formation and propagation of a new type of highly nonlinear solitary waves with compact support. The interaction of these solitary waves with an interface between two strongly nonlinear discrete granular media results in novel dynamic phenomena. Here we present a detailed study of the behavior of the reflected and transmitted waves at the interface between two media composed of spherical beads with dramatically different elastic properties and the influence of the static precompression on their formation and propagation. The presence of static precompression can be effectively utilized to monitor the information flow through the interfaces. The formation of anomalous waves caused by the selective ability of the media to support compressive or rarefaction stationary pulses is presented for interfaces of various materials and investigated numerically and experimentally.

[1]Support from NSF Grant N. DCMS03013220 is greatly appreciated.

4:54PM W30.00013 Topology of the intermediate state in pinning-free type-I superconductors of different shapes[1]

JACOB R. HOBERG, RUSLAN PROZOROV, Ames Laboratory and Department of Physics & Astronomy, Iowa State University, Ames IA 50011 — Equilibrium patterns of the intermediate state were studied in pinning-free Pb samples of different shapes by using direct magneto-optical visualization as well as AC and DC susceptibility measurements. It is found that equilibrium topology of the intermediate state in spheres and hemispheres consists of flux tubes both on flux penetration and exit. Samples with geometric barrier (two flat surfaces perpendicular to an applied magnetic field) exhibit topological hysteresis (and corresponding magnetic hysteresis) – tubes for flux penetration and Landau laminar structure on flux exit. Finally, obtuse-cone shaped samples show laminar structure both on penetration and exit. Based on the experimental results, general discussion of the equilibrium topology of the intermediate state is given. Video of real-time intermediate state evolution with an applied field for various samples is available at: http://www.cmpgroup.ameslab.gov/supermaglab/video/Pb.html

[1]Supported by NSF Grant DMR-05-53285 and the Alfred P. Sloan Research Foundation.

5:06PM W30.00014 Continuum Model for Chaotic Pattern Dynamics on Au Surfaces Sputtered by Focused Ion Beam

KEVIN MITCHELL, UBC Dept of Phys. & Astro., ARVIN YAZDI, UBC Dept. of Phys. & Astro., TOM TIEDJE, UBC Dept of Phys. & Astro. / Dept. Elec. & Comp. Eng. — Under bombardment by a rastered 30keV Ga^+ ion beam, a flat Au surface is found to exhibit the well known sputter ripple instability with a characteristic lateral length scale on the order of 100nm and an RMS saturation height on the order of 10nm. Using *in situ* SEM imaging, we are able observe the dynamics of these ripples as they form and evolve. Accurate topography data is also gathered using *ex situ* AFM. These experimental data are compared to 2D numerical solutions of the dimensionless partial differential equation $\partial_t h = -\nabla^2 h - \nabla^4 h - \alpha |\nabla h|^2 + \beta \nabla^2 |\nabla h|$, which capture the essential features of the sputter ripples. A semi-implicit spectral method is used to solve the equation on a 128×128 grid covering a $20(2\pi) \times 20(2\pi)$ periodic domain. A length scale near $2\pi\sqrt{2}$, consistent with linearized stability is observed, as is a saturation height of order 1 when the constraint $\alpha^2 + \beta^2 = 1$ is enforced. Interestingly, the ratio α/β is found to control the timescale of the chaotic post-saturation dynamics in addition to fine tuning the length and height scales.

5:18PM W30.00015 Degenerate four-wave mixing with defocusing nonlinearity

JASON FLEISCHER, WENJIE WAN, SHU JIA, Princeton University — We experimentally demonstrate four-wave mixing (FWM) effects in a defocusing nonlinear photorefractive medium, in both one and two dimensions. By using a rectangular crystal, we observe the nonlinear generation of new (spatial) frequencies as a function of propagation distance. Both position-space and momentum-space images are taken, allowing a detailed study of dynamical energy transfer. For degenerate FWM, consisting of a cos(kx) profile superimposed on a k=0 background, there is a direct energy cascade to higher momenta (smaller spatial scales). For the asymmetric case, sum- and difference-frequency generation leads to complex patterns. In two dimensions, interactions also lead to a change in the spatial geometry. Numerical simulations show excellent agreement with the experimental results.