CPP 16: SYMPOSIUM Driven Soft Matter I

Time: Tuesday 9:30–12:30 Location: C 130

Invited Talk CPP 16.1 Tue 9:30 C 130
Imaging the flow of concentrated colloidal suspensions — •Wilson Poon, Lucio Isa, and Rut Besseling — The University of Edinburgh, Scotland, UK

Recent advances in confocal microscopy allow us to image the flow of concentrated colloidal suspensions at single-particle resolution in real time. I will describe results from recent experiments on suspensions of hard spheres at packing fractions of 60% or higher. At zero applied stress, these suspensions behave like amorphous solids ('colloidal glasses'). We have used fast confocal imaging to study the yielding of such suspensions under simple shear, as well as their flow in rectangular capillaries. In both cases, direct imaging has revealed a rich variety of phenomena not predicted by traditional rheological theory treating dense suspensions as yield stress fluids. In the case of pipe flow, we find that a theory previously proposed for granular materials can give a good account of certain aspects of our observations.

Invited Talk CPP 16.2 Tue 10:00 C 130
Stochastic thermodynamics of driven soft matter — •Udo Seifert — II. Institut fuer Theoretische Physik,Universitaet Stuttgart

Stochastic thermodynamics provides a conceptual framework for describing small systems embedded in a heat bath and mechanically or by external flow driven to non-equilibrium. Both the first law and entropy production can be consistently defined along single trajectories. An infinity of integral fluctuation theorems hold, among which the Jarzynski relation and the one on total entropy production are prominent ones [1]. After briefly reviewing and illustrating these foundations using a driven colloidal particle as paradigm, I will present within this scheme our recent work concerning (i) optimal finite-time processes and (ii) extended fluctuation-dissipation theorems (FDTs) and generalized Einstein relations. The optimal protocol of an external control parameter minimizes the mean work required to drive the system from one given equilibrium state to another in a finite time. Explicit solutions both for a moving laser trap and a time-dependent strength of such a trap show finite jumps of the optimal protocol to be typical both at the beginning and the end of the process [2]. The Einstein relation connecting diffusion constant and mobility is violated beyond the linear response regime. Based on our recent extension of the FDT [3], we have derived and measured an additive correction term which involves an integral over measurable correlation functions [4].

[1] U. Seifert, PRL 95: 040602, 2005. [2] T. Schmiedl and U. Seifert, PRL 98: 108301, 2007. [3] T. Speck and U. Seifert, EPL 74: 391, 2006. [4] V. Blickle, T. Speck, U.S., C. Bechinger, PRL 98: 210601, 2007.

Invited Talk CPP 16.3 Tue 10:30 C 130
Spatial cooperativity in soft glassy flows — •Lydéric Bocquet — Lyon University and Technical University Munich

Amorphous glassy materials of diverse nature – concentrated emulsions, granular materials, molecular glasses – display complex flow properties, intermediate between solid and liquid, which are at the root of their use in many applications. A classical feature is the very non-linear nature of the flow rule relating stresses and strain rates. In this talk, I will present recent experimental results for the flow of thin layers of concentrated emulsions which, beyond the classical non-linearities of the rheological behaviour, demonstrate the existence of finite size effects in the flow behavior and the absence of an intrinsic local flow rule. In contrast, a rather simple non-local flow rule is shown to account for all the velocity profiles. This non-locality of the dynamics is quantified by a length, characteristic of the cooperativity of the flow at these scales, that is unobservable in the liquid phase (lower concentrations) and that increases with concentration in the jammed phase. These results will be discussed in the context of a generic elasto-plastic description for the flow dynamics, describing the non-local collective dynamics of the localized plastic events occuring during the flow. Beyond its practical importance for applications involving thin layers, e.g. coatings, our assessment of non-locality and cooperativity echoes observations on other glassy, jammed and granular systems, suggesting a possible fundamental universality.

break

CPP 16.4 Tue 11:15 C 130
Experimental investigation of shear banding in wormlike micelles — •Sébastien Manneville[1], Lydiane Bécu[2], Jean-Baptiste Salmon[3], and Annie Colin[3] — [1]Laboratoire de Physique - Ecole Normale Supérieure de Lyon, 46 allée d'Italie, 69364 Lyon cedex 07, France — [2]CNRS - Université du Maine, Avenue Olivier Messiaen, 72085 Le Mans, France — [3]Rhodia Lab of the Future - CNRS, 178 avenue du Docteur Schweitzer, 33608 Pessac, France

Under simple shear some complex fluids may separate into bands of widely different viscosities. This phenomenon is known as "shear banding" and involves inhomogeneous flows where macroscopic bands bearing different shear rates coexist in the sample. In the last decade, "wormlike micelle" solutions have emerged as a model system to study shear banding. Depending on the concentration, these self-assembled surfactant systems constituted of long, cylindrical, semi-flexible aggregates undergo a shear-induced transition from a viscoelastic state of entangled micelles to a state of highly aligned micelles.

In this talk, we will describe two velocimetry techniques, based on dynamic light scattering and ultrasonic velocimetry respectively, that may be used in combination with conventional rheometry to investigate shear banding with high spatial and temporal resolutions. Experimental results will be presented, where shear-banded flows of wormlike micelles are shown to involve complex spatiotemporal behaviors and apparent wall slip. Such observations, confirmed by recent measurements from other groups, raise lots of open questions that we shall address in the last part of the talk.

CPP 16.5 Tue 11:30 C 130
Rheology and particle tracking on soft colloidal suspensions with tunable glassines — Eko Hari Purnomo, •Dirk van den Ende, Michel Duits, Siva Vanapalli, and Frieder Mugele — Physics of complex fluids, University of Twente, the Netherlands

We studied both the macro- and micro- rheology of soft thermosensitive microgel suspensions that can be tuned continuously and reversibly between the glassy state at low and the liquid state at high temperature. In the glassy state, the rheological properties (G', G'', and J) of the suspensions depend strongly on their age [1]. They can be described quantitatively by the soft glassy rheology (SGR) model. The underlying mechanism for the aging is the increase of the structural relaxation time τ_s as the system ages. To test for micro-rheological propertiesc we determined the mean square displacement (MSD) of probe particles, embedded in the system. The MSD values were obtained from particle tracking using a Confocal Scanning Laser Microscope. This technique provides not only the MSD values but also the displacement distributions and the time evolution of single particle displacements, which are indicative for heterogeneity of the suspension. In this paper we will discuss the non Gaussian properties of our suspension at different levels of glassines as well as the relation between these properties and the macro-rheology.

[1] E.H. Purnomo, D. van den Ende, J. Mellema, and F. Mugele, Phys. Rev. E. 76, 021404 (2007).

CPP 16.6 Tue 11:45 C 130
Diffusion and Taylor dispersion in a simple glass under shear — •Fathollah Varnik — Max-Planck Institut für Eisenforschung, Düsseldorf, Germany

We investigate, via MD simulations of a simple glass, large scale dynamics under homogeneous shear by evaluating the time dependence of the mean square displacements for temperatures ranging from the supercooled state to far below the mode coupling critical temperature of the model. Particularly long simulations are performed allowing an accurate determination of the diffusion constant. For low temperatures and at not too high shear rates, the mean square displacements exhibit the well known two step relaxation behavior with a long time diffusive motion along the spatial directions perpendicular to the flow. In the flow direction, on the other hand, a third regime follows the diffusive motion, where Taylor dispersion with the typical t^3 time dependence clearly dominates the long time behavior of the particle displacements. Once this contribution is subtracted, normal diffusive behavior is recovered in the limit of long times. Comparing diffusive motion along the flow, the shear gradient and the vorticity (neutral) directions reveals small but systematic anisotropy in particle dynamics.

CPP 16.7 Tue 12:00 C 130

A binary Yukawa mixture under shear: A computer simulation study of the transient dynamics — •Jochen Zausch[1] and Jürgen Horbach[2] — [1]Inst. f. Physik, Universität Mainz, Staudinger Weg 7, 55099 Mainz — [2]Inst. f. Materialphysik im Weltraum, DLR, Linder Höhe, 51147 Köln

Very recently, experiments and computer simulations have demonstrated that shear strongly affects transport properties of an undercooled liquid. If the shear rate $\dot{\gamma}$ exceeds the typical relaxation time τ of the system, an acceleration of the dynamics is observed which is reflected, e.g., in a decrease of the shear viscosity (shear thinning). The underlying mechanism of this change is still not well understood on a microscopic level.

We use extensive molecular dynamics simulations to elucidate the transient dynamics of a sheared binary Yukawa mixture from equilibrium to steady state, after a constant shear field is switched on. By inspection of the density-density correlation function we find that the steady state is reached after a time of the order of $\dot{\gamma}^{-1}$. The same is true for the stress that is built up upon increasing strain. The linear velocity profile on the other hand develops in a much shorter time. Similar simulations are performed for the case when a sheared system falls back to equilibrium after shear is switched off. Interestingly, the stress decays as fast as it was built up although the system is still far from equilibrium.

CPP 16.8 Tue 12:15 C 130

Slip and shear-banding in hard-sphere colloidal glasses — •Rut Besseling[1], Pierre Ballesta[1], Lucio Isa[1], George Petekidis[2], and Wilson Poon[1] — [1]School of Physics, University of Edinburgh, Scotland, UK — [2]Inst. Elec. Structure and Laser-FORTH, Heraklion, Crete, Greece

We study slip and flow of colloidal hard-sphere glasses by cone-plate rheometry and simultaneous confocal microscopy, both for microscopically smooth shearing surfaces and for surfaces with particle scale roughness. For smooth walls, the global rheology shows a crossover from Bingham-like slip behaviour at small applied shear rates to a Herschel-Bulkley response at large rate. The velocity profiles show that the *slip to shear* transition is position dependent and we present a phenomenological model that quantifies both local and global rheology. We show that Bingham-type slip is directly connected with the onset of yield stress and that it is generic for hard-sphere glasses at smooth, non-sticky walls.

For rough boundaries, we find global Herschel-Bulkley flow curves, but the associated velocity profiles show marked non-linearity's, developing into strong localization (coexistence of solid and sheared regions) just above the yield stress. This localization has its onset at the glass transition -i.e. flow is uniform for the colloidal fluid- and becomes more pronounced at larger densities. We discuss the possible role of microscopic stress fluctuations as origin for the shear localization.