

## CPP 24: Micro and Nano Fluidics II: Soft Objects in Flow + Slippage

Time: Thursday 9:30–12:30

Location: H37

**Invited Talk**

CPP 24.1 Thu 9:30 H37

**Fluctuating 2d vesicles in hydrodynamic Stokes flow** — ●REIMAR FINKEN and UDO SEIFERT — II. Institut für Theoretische Physik, Pfaffenwaldring 57, 70550 Stuttgart, Germany

The behaviour of soft objects in hydrodynamic flow has received increasing attention in recent years, both theoretically and experimentally. An important and intriguing aspect is the interaction of the flow with thermal fluctuations in this non-equilibrium situation. As a paradigmatic model system we study the stochastic motion of a vesicle with a one dimensional membrane in a planar shear flow. At large shear rate the hydrodynamic forces stretch out the membrane fluctuations. The simplified geometry allows easier analytic treatment and makes the system amenable to computer simulations. We develop a theory which takes advantage of small deviations from a circular shape and obtain Langevin type equations of motion for the deformation amplitudes. Analytic expressions are obtained for the stationary state and for the correlation functions of the deformation. Our analytic results are compared with simulation data. This work was funded by the DFG Priority Program SPP 1164 “Nano- and Microfluidics”.

CPP 24.2 Thu 10:00 H37

**Spontaneous stretching of DNA in a two-dimensional nanoslit** — ●MADHAVI KRISHNAN and PETRA SCHWILLE — Institut für Biophysik, Biotechnologisches Zentrum der TU Dresden, 01307 Dresden, Germany

We report a novel regime of polyelectrolyte behaviour manifested in the stretching of DNA molecules confined in solution to two dimensions that arises from the combined effects of confinement and electrostatics in nanoslits. We observe that a proportion of DNA molecules in slit-shaped silicon dioxide-glass channels, a few microns wide and 50 to 100 nm deep, spontaneously assumes axially extended configurations at the lateral sidewalls of the slit, exhibiting thermal fluctuations in contour length predominantly along the major axis of the slit. The situation resembles that of extension of a physically confined polymer chain in a nanochannel, with the important exception that the nanochannel confines the DNA molecule in two of three spatial dimensions, while the nanoslit involves actual physical confinement in only one spatial dimension; confinement in the second spatial dimension is gratuitous, and appears to be electrostatically mediated. The spontaneous ordering and extension of DNA molecules in fluidic slits with depths comparable to persistence length of DNA, is not only of fundamental relevance in understanding electrostatic interactions between confined charged entities but also offers a novel, greatly simplified method to stretch DNA in solution for DNA-protein interaction studies.

CPP 24.3 Thu 10:15 H37

**Brownian dynamics of microswimmers** — ●VLADIMIR LOBASKIN — Physics Department T37, Technical University of Munich, 85747 Garching, Germany

We perform computer simulation of few simple model microswimmers consisting of three spheres and propelling themselves in a fluid by non-reciprocal body reshaping cycle at low Reynolds numbers. We find that the stationary velocity of the swimmers can be described by an universal scaling law and grows as a square of the beating amplitude and linear in the beating frequency. We show that the performance of coupled swimmers scales linearly with their number. In presence of fluctuations, the microswimmers display random walk trajectories. The characteristics of the trajectory and the velocity distribution change qualitatively upon variation of the stationary swimming velocity at fixed temperature. We observe a Gaussian random walk and Maxwellian velocity distribution in the weak-beating regime and crater-like velocity distribution, typical for driven systems, in the strong-beating regime. The transition to the driven regime as well as the corresponding force-velocity relation for the microswimmers can be described by a Langevin theory of active Brownian motion.

CPP 24.4 Thu 10:30 H37

**Determination of density, viscosity and activation energy of small liquid volumes using an atomic force microscope** — ●NEAL MCLOUGHLIN, STEPHEN LEE, and GEORG HÄHNER — *EaStCHEM* School of Chemistry and *SUPA* School of Physics; University of St Andrews; St Andrews KY16 9ST UK

We demonstrate that the viscosity and density of small liquid volumes can be determined with good precision from the resonance spectra of both magnetically driven and thermally excited AFM cantilevers. Recording spectra depending on the temperature allows for the determination of activation energy values. Data recorded in water were employed to extract parameters characteristic of the resonance behaviour of the system. These parameters were then used to determine the properties of further liquid samples. The method we present is fast and reliable and does not require a calibration of the force constant of the cantilever or knowledge of its geometry. It can be performed with commercial instruments and has the potential to be incorporated in microfluidic systems [1].

[1] N. McLoughlin, S. L. Lee, G. Hähner *Appl. Phys. Lett.* **89**, 184106 (2006)

**15 min. break**

CPP 24.5 Thu 11:00 H37

**Rupture and collapse dynamics of thin liquid films** — ●FRANK MÜLLER and RALF STANNARIUS — Institut für Experimentelle Physik, Otto-von-Guericke Universität, 39106 Magdeburg, Germany

Equilibrium shapes of thin free-standing liquid membranes are well understood. On the other hand, when such films undergo fast configurational transitions like the rupture of spherical bubbles or the collapse of catenoids [1], different dynamical mechanisms are involved, and such processes are in general poorly understood. We study such phenomena experimentally, using smectic liquid crystal membranes and a fast camera (up to 100 kfps). From the time resolved image analysis, we determine the influences of different processes involved, like collection of the excess material in a rim, global flow in the film towards the meniscus and global thickening of the film. The role of these mechanisms is controlled by the viscosity, the thickness of the film and influences of the surrounding air.

[1] Müller F and Stannarius R: Collapse dynamics of catenoid-shaped smectic films, *Europhys. Lett.* 2006, in press

CPP 24.6 Thu 11:15 H37

**Ratchet driven microfluidic transport: the case of two liquid layers** — ●UWE THIELE<sup>1</sup> and KARIN JOHN<sup>2</sup> — <sup>1</sup>Max-Planck-Institut fuer Physik komplexer Systeme, Noethnitzer Str. 38, 01187 Dresden, Germany — <sup>2</sup>Laboratoire de Spectrométrie Physique, Université Joseph Fourier Grenoble I, BP 87 - 38402 St.-Martin-d'Hères Cedex, France

We extend our previously derived model for ratchet-driven microfluidic transport [1] to the case of two layers of immiscible liquids confined in a capacitor.

The transport relies on field-induced morphological changes of the free liquid-liquid interface based on a switchable, spatially asymmetric, periodic interaction of the liquid-liquid interface and the substrates. The concept is exemplified using an evolution equation for the profile of the interface between two dielectric liquid layers under an spatially inhomogeneous, time-periodic voltage. We analyse the influence of the various phases of the ratchet cycle on the transport properties.

We discuss conditions for maximal transport for the case of periodic switching between two potentials differing by translation in space by half a period. This constellation allows for the transport of droplets of liquid 1 in liquid 2.

[1] K. John and U. Thiele, <http://arxiv.org/abs/physics/0611144> (2006).

CPP 24.7 Thu 11:30 H37

**Microrheology on (DNA-grafted) colloids using Optical tweezers** — ●CHRISTOF GUTSCHE<sup>1</sup>, ULRICH KEYSER<sup>1</sup>, KATI KEGLER<sup>1</sup>, MATHIAS SALOMO<sup>2</sup>, and FRIEDRICH KREMER<sup>1</sup> — <sup>1</sup>Univ Leipzig, Inst Expt Phys 1, Leipzig, Germany — <sup>2</sup>Univ Leipzig, Inst Biochem, Leipzig, Germany

Optical Tweezers are employed to measure the forces of interaction within single pairs of (DNA-grafted) colloids in media of monovalent and divalent ionic aqueous solutions of varying concentrations. For monovalent ions the data for the blank colloids are well described by

the DLVO theory but as well by a novel Poisson-Boltzmann approach. Additional parameters to be varied for grafted colloids are the length of the DNA and the grafting density. From the measured force-separation dependence an interaction length at a given force is deduced. It shows in the "mushroom" regime a scaling with the grafting density which levels off for brushes [1]. The flow resistance of single blank or DNA-grafted colloids is determined and compared. The degree of swelling of the grafted DNA is adjusted by exchanging the ion concentration of the surrounding medium. For all examined flow velocities one observes an interesting deviation from Stokes law which can be traced back to a shear-dependent conformational change of the brush layer [2].

[1] K. Kegler, M. Salomo, and F. Kremer, in *Press Phys. Rev. Lett.* (2006) [2] C. Gutsche, M. Salomo, Y.W. Kim, R.R. Netz and F. Kremer, *MICROFLUIDICS AND NANOFUIDICS* 2 (5): 381-386 SEP (2006)

CPP 24.8 Thu 11:45 H37

**Motion of polymer droplets on soft substrates: A Molecular Dynamics Study** — ●MARCUS MULLER<sup>1</sup>, CEM SERVANTIE<sup>1</sup>, and CLAUDIO PASTORINO<sup>2</sup> — <sup>1</sup>Institut fuer Theoretische Physik, Georg-August Universitaet, Goettingen — <sup>2</sup>Comission Nacional de Energia Atomica, Physics, Buenos Aires, Argentina

Brushes are soft, elastically deformable substrates giving rise to a rich wetting behavior and additional molecular dissipation mechanisms for the motion of droplets. We study thin polymer films and droplets on flat brush-covered substrates by non-equilibrium molecular dynamics simulation of a coarse-grained bead-spring model. The brush consists of identical polymers as the droplets.

Upon increasing the grafting density the free polymers are expelled from the brush and a brush-melt interface gradually builds up. Molecular conformations and the overlap between brush and melt are studied in equilibrium and under shear. The velocity profile across a thin polymer film is investigated. The slip length adopts large positive values (perfect slip) for low grafting densities, but decreases and becomes negative for densely grafted, autophobic brushes.

At high grafting density the polymer melt dewets from the brush and forms droplets. Nanoscopic polymer droplets driven by volume forces are investigated in their steady state.

CPP 24.9 Thu 12:00 H37

**Impact of the solid/liquid interface on the flow dynamics of thin polymer films** — ●OLIVER BÄUMCHEN, RENATE FETZER, and KARIN JACOBS — Saarland University, Experimental Physics, D-66041 Saarbrücken, Germany

We investigate the boundary conditions at the solid/liquid interface

of thin film flow of highly viscous Newtonian liquids. To induce flow, we use the dewetting process which starts by the nucleation of holes. In our system, low molecular weight polystyrene melts dewet from hydrophobic substrates after annealing above their glass transition temperature. By investigating the radii of growing circular holes, we find that the dewetting velocity at a constant temperature strongly depends on the type of substrate. We could show that in the case of silicon wafers covered by different silane brushes (octadecyltrichlorosilane and dodecyltrichlorosilane) hole growth can be described by a superposition of viscous flow and slippage. A novel data analysis method is used to identify the two velocity contributions, viscous flow and slippage, and to extract the slip length. The numbers for the slip length are consistent with results obtained from SPM analysis of rim profiles [1]. This latter method could be connected to a lubrication model derived from the Navier-Stokes equations with a Navier-slip condition and enables us to determine the slip length as well as the viscosity of the polymer melt. The variation of further system parameters such as substrate properties allows us to obtain more detailed information about the mechanism of slippage at the interface on a molecular level. [1] R. Fetzer et al., *Europhys. Lett.* 75 (2006) 638

CPP 24.10 Thu 12:15 H37

**Boundary flow on superhydrophobic surfaces** — ●AUDREY STEINBERGER<sup>1</sup>, CECILE COTTIN-BIZONNE<sup>2</sup>, and ELISABETH CHARLAIX<sup>2</sup> — <sup>1</sup>MPI for Dynamics and Self-Organization, Göttingen, Germany — <sup>2</sup>Laboratoire de Physique de la Matière Condensée et Nanostructures – Université Claude Bernard Lyon 1 and CNRS, Lyon, France

With the development of microfluidic systems it becomes important to control flows at small scales for systems characterized by a large surface to volume ratio. A slip hydrodynamic boundary condition can both increase the flow rate at a given pressure gradient, and reduce the hydrodynamic dispersion. Trapping gas in superhydrophobic surfaces has been suggested as a good way to obtain high and controlled slippage.

We have investigated the boundary flow of water-glycerol mixtures on superhydrophobic surfaces, using a dynamic Surface Force Apparatus. Firstly, we show that the entrapped bubbles confer elastic properties to superhydrophobic surfaces. Measuring those elastic properties allowed us to probe the meniscus shape of the bubbles. Secondly, we have shown that, contrary to conventional notions, microbubbles at the solid-liquid interface do not systematically lubricate the interface. Protruding microbubbles can strongly reduce the slippage instead. The control of the meniscus shape is thus a key point to control the slippage and has to be integrated into the conception of the design of microsystems.