CPP 22 SYMPOSIUM Microfluidics II: Soft objects in flow, open geometries

Time: Thursday 14:00–17:00 Room: ZEU 160

Invited Talk

CPP 22.1 Thu 14:00 ZEU 160

Confinement and manipulation of single molecules in micro- and nanochannels — •Petra Schwille, Fedor Malik, Petra S. Dittrich, and Madhavi Krishnan — Institute for Biophysics, Biotechnology Center, Technical University Dresden

Micro- and nanofluidic structures are ideally suited to observe and manipulate minute amounts of biomolecules under close-to-native conditions without tedious and error-prone immobilization to surfaces. In particular, soft polymer structures such as PDMS can be easily adapted to host several manipulation steps, e.g. for solution mixing and cell or particle sorting on one chip, and at the same time allow to analyze the solution by high resolution optics such as single molecule fluorescence spectroscopy. We discuss several successful and promising microfluidic applications, such as for enzyme kinetics, particle sorting, and the design of a chip allowing for the generation of $\sim 5\mu$m sized homodisperse droplets that contain the reaction mixture for cell-free protein expression, as a basic model for what could be developed into artificial cells.

Recently, we devised a strategy to quantitatively study the translocation of DNA binding proteins, such as helicases, restriction endonucleases and exonculeases at the single molecule level by scaling down the structure sizes to nanochannels whose dimensions approach the persistence length of DNA (50-60 nm). The method is based on the entropic stretching of DNA in confined structures, and the subsequent application of fluorescence techniques such as bright field fluorescence microscopy and/or Fluorescence Correlation Spectroscopy to quantify transport coefficients of enzymes that translocate along the DNA backbone

CPP 22.2 Thu 14:30 ZEU 160

Dynamics and Formation of Actin Bundles in Extensional Flow — •Dagmar Steinhauser, Sarah Köster, and Thomas Pfohl — Max-Planck-Institut für Dynamik und Selbstorganisation, Bunsenstrasse 10, 37073 Göttingen

We are interested in the dynamics of biopolymers under extensional flow and the formation of condensed structures, bundles and networks, induced by inter-chain and intra-chain linker molecules. In particularly the bundling behavior of actin filaments in presence of actin binding proteins (e.g. α-actinin) or multivalent ions is considered. Actin filaments as well as their bundles and networks are visualized in continuous flow by stroboscopic laser light illumination. Using a hydrodynamic focusing device we are able to observe the evolution of the bundling of individual filaments. A detailed analysis of the fluctuations of the formed bundles leads to information about their stiffness in dependence on the number of actin filaments.

CPP 22.3 Thu 14:45 ZEU 160

Electrophoretic mobility of DNA from Lattice Boltzmann simulations — •Sandeep Tyagi[1] and Christian Holm[1,2] — [1]Frankfurt Institue for Advanced Studies, Max-von-Laue-strasse 1, D-60438 Frankfurt am Main, Germany — [2]Max-Planck-Institut für Polymerforschung, Ackermannweg 10, D-55128 Mainz, Germany

We investigate the electrophoretic motion of DNA of various length under the influence of an applied DC electric field in the bulk and under confinement. The simulation method uses an implicit solvent model with an effective dielectric permittivity, but includes both long range hydrodynamic and full electrostatic interactions. The DNA is treated via a semi-flexible bead-spring model. The charged "beads"on the DNA and the associated free counterions are frictionally coupled to the solvent using a lattice Boltzmann solver due to Ahlrichs and Dünweg (J. Chem. Phys, Vol. 111, 1999). This efficient technique that scales linearly with the number of particles is demonstrated to produce experimentally known results for the dependence of the electrophoretic mobilities of DNA on the degree of polymerization. Chain conformations of DNA and the corresponding counterion distribution around the chains at various externally applied electric fields are probed. We also discuss the extension of this technique for studying electrophoretic motion of charged objects in slit-pore including dielectric boundaries.

CPP 22.4 Thu 15:00 ZEU 160

Freely suspended actin cortex models in a controlled microfluidic environment — •Tamas Haraszti[1,2], Simon Schulz[1,2], Wouter Roos[1,2], Christian Schmitz[1,2], Jens Ulmer[1,2], Stefan Gräter[1,2], and Joachim Spatz[1,2] — [1]Max-Planck-Institute for Metals Research, Department New Materials & Biosystems, Heisenbergstr. 3, D-70569 Stuttgart — [2]Biophysical Chemistry, University of Heidelberg, INF 253, D-69120 Heidelberg

Arrays of pillars, microfabricated in PDMS, are constructed to serve as a template for mimicking the actin cortex of cells. The three-dimensional template surface prevents confinement effect on the actin filaments hanging between pillars at a height of about 10 microns. A special flow-cell design enables applying flow -an external driving force- around the network of actin. This unique experimental system opens new possibilities, for example to study the mechanics of two-dimensional actin networks as a function of actin-crosslinkers, to observe the active diffusion of molecular motors operating on pending networks and to investigate the alternations in the transport of microscopic particles, coated by different proteins, along these actin cortex models under the drag of flow.

Such transport problems are studies of tracks and external driving forces (motors, flow) on a statistical process under the influence of order and randomness along two-dimensional networks isolated from the complicated and undetermined cellular environment. The filaments are visualized by fluorescent optical microscopy, and their stiffness can be tuned by bundling of actin filaments through various cross-linkers.

CPP 22.5 Thu 15:15 ZEU 160

Dynamic behaviour of quasi spherical vesicles in Stokes flow — •Reimar Finken and Udo Seifert — II. Institut für Theoretische Physik, Pfaffenwaldring 57 / III, 70550 Stuttgart, Germany

The behaviour of soft objects in hydrodynamic flow has received increasing attention in recent years, both theoretically and experimentally. As a paradigmatic model system lipid bilayer vesicles have been investigated extensively. When the viscosity of the fluids inside and outside the vesicle are the same, theories and computer simulations predict a stationary motion with fixed vesicle shape. For increasing viscosity ratio between inner and outer fluid, a dynamical phase transitions towards an unsteady motion is expected. Both behaviours have been observed experimentally very recently for the first time. We present a fully dynamic three dimensional theory that takes advantage of the small deviations from a spherical shape. The tanktreading to tumbling transition is investigated and compared to the recent experiments. This semi-analytical approach has the merit of becoming exact in the limit of small excess area of the vesicle, while allowing more insight into the underlying physics than a purely numerical scheme. We contrast our results with existing simplified analytic theories, which either assume a fixed shape or a two dimensional geometry. The asymptotic exactness of our approach allows a quantitative discussion of these simplifications.

— 15 min. break —

Invited Talk

CPP 22.6 Thu 15:45 ZEU 160

Unconventional Microfluidics — •Ralf Seemann[1], Jean-Christophe Baret[2], K. Khare[1], Craig Priest[1], and Stephan Herminghaus[1] — [1]MPI for Dynamics and Self-Organisation, Bunsenstr. 10, D-37073 Göttingen, Germany — [2]Philips Research Laboratories, NL-5656AA Eindhoven, The Netherlands

Microfluidics usually involves single phase liquids transported through closed microchannel networks. Instead, we explore open systems with freely accessible liquid interfaces as well as compartmented liquids in closed microchannels. In our project we study the wetting morphologies on topographic substrates and explore the possibility to transport liquid by switching in the various liquid morphologies. The morphologies are determined by the contact angle of the liquid and the geometry of the grooves [1]. Electrowetting is used to tune the contact angle, leading to reversible transitions between a drop-like morphology and extended liquid filaments. The transition is capillarity-driven but the behavior of the liquid above the transition is influenced by the electrical properties of the liquid [2]. Furthermore, we employ monodisperse emulsions to compartment liquids for microfluidic processing. If the volume fraction of the

continuous phase is small, the dispersed compartments (droplets) assemble into well-defined arrangements, analogous to foam. Hence, the position of a single droplet within an ensemble of droplets is fully determined while being transported through microfluidic channels. We demonstrate an in situ method for the production of such monodisperse emulsions, suitable for microfluidic processing [3] and a variety of channel geometries for positioning, sorting, dividing, and selectively induced coalescing of droplets in 'lab-on-chip' style processing.

[1] R. Seemann, et al. PNAS 102, 1848 (2005)
[2] J.-C. Baret, M. Decré, S. Herminghaus, and R. Seemann, Langmuir (in press)
[3] C. Priest, S. Herminghaus, and R. Seemann, Appl. Phys. Lett. (in press)

CPP 22.7 Thu 16:15 ZEU 160

Dissipative Particle Dynamics as a simulation tool for confined nanofluidic systems. — •Björn Henrich[1,2], Claudio Cupelli[3], Michael Moseler[2,1], and Mark Santer[3] — [1]University of Freiburg-FMF,Freiburg Materials Research Center, D-79104 Freiburg, Germany — [2]IWM, Fraunhofer Institute for Mechanics of Materials, Wöhlerstraße 11, D-79108 Freiburg, Germany — [3]University of Freiburg-IMTEK, Department of Microsystem Engineering, Georges-Köhler-Allee 106, D-79110 Freiburg, Germany

Fluid particle methods such as Dissipative Particle Dynamics are continuum simulation approaches to represent fluids, suspensions or polymers on mesoscopic time and length scales. We report how this simulation technique may be applied to study nano scale ($>$ 1nm and $<$ 100nm) impregnation and imbibition phenomena. Pursuing the approach of Warren [1] to account for cohesive properties, we show how adequate solid-liquid interfaces based on "live"walls can be constructed to allow for a variable static contact angle, at the same time avoiding artefacts such as temperature or density oscillations that often occur when rigid walls are used. This model is then utilized to study the impregnation dynamics into a nano slit pore that is filled out of a finite reservoir. We find that the dynamic apparent contact angle within the pore can be determined reliably, and with respect to the capillary number, differs significantly from the one extracted from numerical plug flow experiments.

[1] Phys. Rev. E, 066702 (2003)

CPP 22.8 Thu 16:30 ZEU 160

Ratchet driven microfluidic transport — •Karin John[1] and Uwe Thiele[1,2] — [1]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, D-01187 Dresden, Germany — [2]Lab. Spectrometrie Physique, Univ. J. Fourier - Grenoble I, 140 Av. Physique, 38402 Saint-Martin d'Heres, France

Transport in spatially extended systems can be induced if nonequilibrium fluctuations and a broken spatial symmetry are present [1]. This can be realized using a global gradient or a globally homogeneous system that displays local time-periodic asymmetries, e.g., a flashing periodic asymmetric potential (ratchet). Examples where a diffusive transport is induced are molecular motors [2] or the particle transport through asymmetric pores [3].

We propose a concept for ratchet driven open microfluidic flow, i.e. involving liquid with a free surface, like droplets and films. After introducing the basic principle, a theoretical model in long-wave approximation [4] is presented. It is used to analyse the ratchet-driven convective transport in detail.

[1] R. D. Astumian, Science **276**, 917–922 (1997).
[2] F. Jülicher, A. Ajdari, A. and J. Prost, Rev. Mod. Phys. **69**, 1269–1281 (1997).
[3] S. Matthias and F. Müller, F., Nature **424**, 53-57 (2003).
[4] A. Oron, S. H. Davis and S. G. Bankoff, Rev. Mod. Phys. **69**, 931-980 (1997).

CPP 22.9 Thu 16:45 ZEU 160

Pearling instability of nanoscale fluid flow confined to a chemical channel — •M. Rauscher[1,2], J. Koplik[3], T. S. Lo[3], and S. Dietrich[1,2] — [1]Max-Planck Institut für Metallforschung, Heisenbergstr. 3, 70569 Stuttgart, Germany — [2]Institut für Theoretische und Angewandte Physik, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [3]Benjamin Levich Institute and Department of Physics, City College of the City University of New York, New York, NY 10031, USA

We investigate the flow of a nano-scale incompressible ridge of low-volatility liquid along a "chemical channel": a long, straight, and completely wetting stripe embedded in a planar substrate, and sandwiched between two extended less wetting solid regions. Molecular dynamics simulations, a simple long-wavelength approximation, and a full stability analysis based on the Stokes equations are used, and give qualitatively consistent results. While thin liquid ridges are stable both statically and during flow, a (linear) pearling instability develops if the thickness of the ridge exceeds half of the width of the channel. In the flowing case periodic bulges propagate along the channel and subsequently merge due to nonlinear effects. However, the ridge does not break up even when the flow is unstable, and the qualitative behavior is unchanged even when the fluid can spill over onto a partially wetting exterior solid region.