CPP 27: Micro and Nano Fluidics II: Slipping + soft objects in flow

Time: Thursday 14:00–16:15 Location: C 264

CPP 27.1 Thu 14:00 C 264

Motion of a cylindrical droplet under an external body force — Cem Servantie and •Marcus Müller — Institut für Theoretische Physik, Georg-August Universität, Göttingen

We study the rolling and sliding motion of droplets on a corrugated substrate by Molecular Dynamics simulations. Droplets are driven by an external body force (gravity), and we investigate the velocity profile and dissipation mechanisms in the steady state. The cylindrical geometry allows us to consider a large range of droplet sizes.

The velocity of small droplets with a large contact angle is dominated by the friction at the substrate and the velocity of the center of mass scales like the square root of the droplet size. For large droplets or small contact angles, however, viscous dissipation of the flow inside the volume of the droplet dictates the center of mass velocity that scales linearly with the size.

We derive a simple analytical description predicting the dependence of the center of mass velocity on droplet size and the slip length at the substrate. In the limit of vanishing droplet velocity we quantitatively compare our simulation results to the predictions and good agreement without adjustable parameters is found.

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Flow of thin polymer films on mesoporous silicon surfaces — •Matthias Lessel, Oliver Bäumchen, and Karin Jacobs — Saarland University, Experimental Physics, D-66123 Saarbrücken, Germany

The nature of boundary conditions of fluids at the interface of solid surfaces has become more and more important in recent years due to applications in lab-on-a-chip devices. Reducing the scale of fluidic systems leads to a stronger influence of this interface, which can be described by a parameter called slip length. It can be interpreted as the length below the solid/liquid interfaces where the velocity profile of the liquid extrapolates to zero. Our system consists of thin polystyrene films on top of hydrophobized Si wafers, which are heated above the glass transition temperature to induce dewetting as a driving force for Newtonian flow. The slip length can be extracted by analyzing the growth of a dewetting hole using optical microscopy or, with the help of a Stokes model for thin liquid films, from rim profiles of holes imaged by AFM. In recent experiments we study the influence of structured surfaces on the dewetting dynamics. For this we are using hydrophobized mesoporous Si substrates instead of a smooth Si wafer bearing in mind that the pore diameter and porosity of this material is alterable by parameters of the fabrication process. Moreover they can be probed by spectroscopic ellipsometry using a fit based on a Bruggeman model.

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Dewetting dynamics of thin polymer films on viscoelastic substrates — •Konstantina Kostourou[1], Dirk Peschka[2], Andreas Münch[3], Barbara Wagner[4], Stephan Herminghaus[1], and Ralf Seemann[1,5] — [1]MPIDS, D-37073 Göttingen — [2]Humboldt-University, D-12489 Berlin — [3]University of Nottingham, Nottingham, NG7 2RD, UK — [4]Weierstrass Institute, D-10117 Berlin — [5]Saarland University, D-66041 Saarbrücken

The dewetting of thin liquid polystyrene (PS) films on viscoelastic substrates (PDMS and molten PMMA) is studied both experimentally and theoretically. The dewetting dynamics is found to be slower for smaller substrate elastic moduli. To explore how the dynamics is influenced by the viscoelasticity of the substrate we investigate the shape of the dewetting rim profile and the deformation of the underlying substrate. In case of PMMA substrates we remove the PS using a selective solvent and image the deformation directly on the frozen PMMA. The deformation of rubbery PDMS substrates is reversible. We therefore, lift off the PS from the substrate and image its deformation, which is frozen into the "bottom side"of the dewetting profiles. These techniques even allow to image the deformation of the substrate at the three phase contact line, which is pulled upwards. By quantifying the substrate deformation caused by PS droplets we can derive the elastic modulus of the PDMS substrates in agreement with bulk measurements. We find characteristic rim shapes and deformations of the substrate depending on the elastic modulus and the viscosity of the underlying substrate.

CPP 27.4 Thu 14:45 C 264

Flows driven by wettability gradients: A lattice Boltzmann study — •Fathollah Varnik and Dierk Raabe — Max-Planck Institut für Eisenforschung, Düsseldorf, Germany

Guided motion of liquids is studied via lattice Boltzmann computer simulations. The focus of the work is on basic issues related to driving forces generated via a step-wise (abrupt) change in wetting properties of the substrate along a given spatial direction. We first give approximate analytic expressions for forces driving the liquid motion. These theoretical estimates show qualitatively different dependence of wetting gradient induced forces on contact angle and liquid volume in the case of an open substrate as opposed to a planar channel. These results are then examined via lattice Boltzmann computer simulations. Furthermore, we also investigate effects of a wetting gradient on internal droplet dynamics and the resulting dissipation losses.

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Motion of an elastic capsule in time dependent shear flow — •Steffen Kessler, Reimar Finken, and Udo Seifert — II. Institut für Theoretische Physik, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart

The motion of an elastic three-dimensional micro-capsule in a time dependent shear flow is studied numerically using a spectral method. The shape of the capsule and the hydrodynamic flow field are expanded into smooth basis functions. Analytic expressions for the derivative of the basis functions permit the evaluation of elastic and hydrodynamic stresses and bending forces at specified grid points in the membrane. Compared to methods employing a triangulation scheme, this method has the advantage that the resulting capsule shapes are automatically smooth, and few modes are needed to describe the deformation accurately. Better stability properties compared to simple boundary integral methods follow from this strategy, which has been tested successfully recently in linear shear flow. This code is used to study the response of capsules to a modulated shear flow. We examine both a purely oscillating shear rate and a modulated shear rate around a constant value. In the latter case, we focus on the question whether dynamical phase transitions can be induced by small modulations. Computations are performed for capsules both with spherical and ellipsoidal unstressed reference shape, different elastic parameters, and different viscosity contrasts.

CPP 27.6 Thu 15:15 C 264

Long ranged hydrodynamic repulsion of polymers at interfaces — •Christian Sendner and Roland Netz — Physik Department, Technische Universität München

We consider the influence of a no slip boundary on polymers in external fields or shear flow in the zero Reynolds number regime. Due to the interplay between thermal fluctuations and hydrodynamic interactions, which leads to a preferred orientation of the polymer with respect to the surface, polymers are repelled from the interface with a force that decays with the inverse square of the surface separation. On the basis of a Fokker-Planck analysis, we give scaling relations for this repulsion in terms of length of the polymer, shear strength or external force and temperature. Brownian Dynamic simulations including hydrodynamic interactions confirm these scaling laws. This repulsive force can be used in microfluidic applications to control adsorption and desorption of polymers.

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Cross-Streamline Migration of Semiflexible Actin Filaments in Microflow — •Dagmar Steinhauser, Heather M Evans, and Thomas Pfohl — Max-Planck-Institut für Dynamik und Selbstorganisation, Göttingen

Actin filaments, aside from their biological roles in cellular motility and mechanical stability, also provide an ideal system with which to study, more generally, the properties of semi-flexible polymers. Our experiments investigate the behavior of single actin filaments flowing inside symmetric microchannels with a Poiseuille velocity profile. Fluorescence microscopy using stroboscopic laser light illumination is utilized in order to visualize the moving actin filaments. The dimensions (width and depth) of the channels are in the same order of magnitude as the persistence length as well as the contour length of the filaments. A detailed analysis of the center-of-mass probability distribution along a cross-section of the channel is reported. Depletion layers, found at the walls, can be explained by migration due to hydrodynamic interactions with the walls. In addition, the conformation of the actin filaments in flow depends on the shear stress, which increases towards the walls for Poiseuille flow. The resulting spatially-varying diffusivity leads to a striking migration of filaments away from the center and consequently to a minimum in the center-of-mass distribution at the channel center. Analyzing the change in diffusivity from the measured conformations, the Fokker-Planck equation can be solved and the center-of-mass distributions can be described quantitatively for different velocities.

CPP 27.8 Thu 15:45 C 264

Fluctuating vesicles in hydrodynamic Stokes flow — •Reimar Finken and Udo Seifert — II. Institut für Theoretische Physik, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart

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 out of thermal equilibrium. Thermal noise becomes particularly important near dynamic phase transitions, where the motion is sensitive to external forces. As a paradigmatic model system we study the stochastic motion of a vesicle in a planar shear flow at finite temperature. In the absence of thermal noise, this system exhibits a rich dynamical behaviour including tank-treading, tumbling, and breathing regimes. We consider the stochastic motion of quasi-spherical three dimensional vesicles and develop Langevin type equations of motion for the deformation amplitudes. Near the phase transitions a separation of time scales between the ellipsoidal modes and the higher order modes allows us to treat the higher modes as a bath and study the remaining degrees of freedom using a Fokker-Planck equation. We pay particular attention to the vesicle motion near the "triple point", where the three dynamic regimes meet. This work was funded by the DFG Priority Program SPP 1164 "Nano- and Microfluidics".

CPP 27.9 Thu 16:00 C 264

Hydrodynamic lift forces on solute particles in a nanotube forest — •Vladimir Lobaskin and Roland Netz — Physik Department T37, TU München, 85747 Garching

We apply theory and hybrid Langevin dynamics – lattice Boltzmann simulations to study shear-induced molecular transport in polymer solutions and colloidal dispersios close to an interface modified by a grafted inclined hard posts (carbon nanotube forest) or brush of semi-flexible polymer segments. We show that the excluded volume interactions of particles and polymer chains with the posts lead to appearance of residual hydrodynamic size-dependent lift forces, which can promote a depletion of the solute from the forest or its accumulation at the surface and serve as a basis of sseparation techniques.