CPP 20 SYMPOSIUM Microfluidics I: Boundary conditions, manipulation, and transport

Time: Thursday 09:30–12:30 Room: ZEU 160

Invited Talk CPP 20.1 Thu 09:30 ZEU 160

Interplay of slip and viscoelasticity in dewetting of thin liquid films — •Markus Rauscher[1,2], Andreas Münch[3], Barbara Wagner[4], and Ralf Blossey[5] — [1]Max-Planck-Institut für Metallforschung, Heisenbergstr. 3, 70569 Stuttgart — [2]Institut für Theoretische und Angewandte Physik, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart — [3]Institut für Mathematik, Humboldt Universität Berlin, 10099 Berlin — [4]Weierstrass Institut für Angewandte Analysis und Stochastik, Mohrenstr. 39, 10117 Berlin — [5]Interdisciplinary Research Institute, c/o IEMN Avenue Poincaré BP 60069, F-59652 Villeneuve d Ascq, France

The dynamics of dewetting thin liquid films and the resulting film morphologies have been topic of intense research and great progress (experimental and theoretical) has been made. In particular the influence of the interplay between the rheology of the liquid and the slip at the liquid-substrate interface on the shape of dewetting fronts has been discussed in great detail.

We discuss the dewetting dynamics of thin slipping viscoelastic and Newtonian films in hydrodynamic thin film models based on generalized Maxwell or Jeffreys models. Depending on the ratio of slip length to film thickness one obtains different slip regimes and different thin film models. For weak slip with slip lengths smaller than the film thickness our model predicts dewetting fronts which decay towards the resting film in an oscillatory fashion, independent of the rheological properties of the fluid. But strong slip can lead to monotonically decaying fronts even for Newtonian fluids, as confirmed by recent experiments.

CPP 20.2 Thu 10:00 ZEU 160

Polymer melts slip over solid surfaces: Experimental studies of the slip length — •Renate Fetzer[1], Markus Rauscher[2], and Karin Jacobs[1] — [1]Dept. of Experimental Physics, Saarland University, D-66123 Saarbrücken, Germany — [2]MPI for Metal Research, D-70569 Stuttgart, Germany

We present a novel method to asses the slip length and viscosity of thin films of highly viscous Newtonian liquids. We quantitatively analyze dewetting fronts of low molecular weight polystyrene melts on Octadecyl- (OTS) and Dodecyltrichlorosilane (DTS) polymer brushes. Using a thin film (lubrication) model derived in the limit of large slip lengths, we can extract slip length and viscosity of films with thicknesses between 50 nm and 230 nm and temperatures above the glass transition. We find slip lengths from 100 nm up to 1 micron on OTS and between 300 nm and 10 microns on DTS covered silicon wafers. The slip length decreases with temperature. The obtained values for the viscosity are consistent with independent measurements.

CPP 20.3 Thu 10:15 ZEU 160

Single Molecule Diffusion in Confined Liquids under Shear — •Arne Schob and Frank Cichos — Photonics and optical materials, Institute of physics, TU Chemnitz, 09107 Chemnitz

The liquid-solid boundary is of fundamental importance for microfluidics, chromatography, lubrication and many other applications. Accessing the details and especially the molecular dynamics in this boundary region, however, involves a number of difficulties due to the fact that liquids dynamics varies on a length scale of a few nanometers. We present for the first time experiments that are based on the tracking of single dye molecules in liquid films confined in a surface forces apparatus. Our setup allows to follow molecular motion in liquid films of a few nanometer thickness and under applied shear flow. Employing a new method of single molecule diffusion analysis, we are able to separate the imposed shear velocity from the single molecule diffusion with an extremely high accuracy. Shear displacements of 8 nm within 15 ms can be detected even though diffusional displacements are at least by one order of magnitude larger. The studies on confined films of tetrakis(2-ethylhexoxy)silane demonstrate, that down to a film thickness of 10 nm no change in the effective viscosity of the liquid at the solid boundary occurs. Contrary to recent literature reports, no dependence of the diffusion constant on the shear rate is found.

CPP 20.4 Thu 10:30 ZEU 160

Factors affecting the determination of hydrodynamic slip by using the colloidal probe technique — •Elmar Bonaccurso, Benoit Semin, and Svetlana Guryianova — Max-Planck-Institut für Polymerforschung

Recently, new insight has been gained in describing the boundary condition for the flow of a liquid on a solid, especially in microfluidic devices and other types of highly confined geometries. There is experimental evidence that the no-slip boundary condition, as usually applied for modeling macroscopic fluid flows, may break down at the nanometer scale, and that it might be replaced by a partial-slip boundary condition. One of the experimental techniques able to reveal the occurrence of slip at this scale is the colloidal probe technique: a micron-sized, spherical bead is attached to an atomic force microscope cantilever and pushed towards a solid, flat surface in the liquid which is tested. By measuring the interaction between sphere and surface, one can indirectly infer the velocity of the liquid at the boundary. Here we present a number of factors which affect such a measurement, thus allowing to determine/exclude the presence of slip and eventually helping to quantify it.

— 15 min. break —

Invited Talk CPP 20.5 Thu 11:00 ZEU 160

Sorting in Structured Microfluidic Devices — •Alexandra Ros[1], Jan Regtmeier[1], Thanh Tu Duong[1], and Dario Anselmetti[2] — [1]Bielefeld University, Experimental Biophysics and Applied Nanoscience, Universitaetsstr. 25, 33615 Bielefeld, Germany — [2]Biefeled University, Fakulät für Physik, D-33615 Bielefeld

Suitably tailored microfluidic devices open access to unexpected dynamics and migration phenomena for colloidal particles and molecules. Recently, absolute negative mobility, i.e. the motion opposite to a net acting force, was observed in a lab-on-a-chip for colloidal particles [1]. This non-equilibrium effect is based on Brownian motion and non-linear dynamics induced by microstructuring. Exploiting the sensitive dependence of this paradoxical effect on basic particle properties, we demonstrate the simultaneous migration of two different species of alike-charged particles into opposite directions. The application of this new migration phenomenon for the separation or sorting of biomolecules, cell compounds and cells will be discussed.

[1] A. Ros, R. Eichhorn, J. Regtmeier, T. Duong, P. Reimann, D. Anselmetti, Nature **436**, 928 (2005)

CPP 20.6 Thu 11:30 ZEU 160

Modeling particle motion in structured microfluidic devices — •Ralf Eichhorn and Peter Reimann — Universität Bielefeld, Fakultät für Physik, D-33615 Bielefeld

The motion of a colloidal particle in a structured microfluidic system under the influence of externally applied electric fields is modelled, including electroosmotic and electrophoretic effects as well as thermal fluctuations. The theory is applied to a microfluidic lab-on-a-chip known to exhibit absolute negative mobility [1] (i.e. net motion opposite to the net acting force) and predicts that two different species of like-charged particles may simultaneously migrate into opposite directions for suitable electric driving fields.

[1] A. Ros, R. Eichhorn, J. Regtmeier, T. Duong, P. Reimann, D. Anselmetti, Nature 436 , 928 (2005)

CPP 20.7 Thu 11:45 ZEU 160

Fluid transport in microchannels induced by high frequency travelling electric waves — •Maika Felten[1], Magnus Jäger[2], Peter Geggier[2], and Claus Duschl[1] — [1]Fraunhofer-Institut für Biomedizinische Technik, Invalidenstraße 42, 10115 Berlin — [2]Universität des Saarlandes, Ensheimer Straße 48, 66386 St. Ingbert

Presently, the handling of fluid volumes in the nanoliter range suffers from a lack of suitable pumping methods. This severely limits the impact of lab-on-chip applications in biotechnology and cell biology. For the creating of a fluid flow in microchannels, we use a combination of temperature fields and high-frequency electric fields that act on the fluid. The temperature field induces inhomogeneities of the permittivity and / or conductivity of the medium. Together with the electric field, this creates volume charges in the liquid bulk which in turn interact with the electric field. To induce a certain flow direction, the electric potential is applied as a sinus-shaped wave travelling parallel to the channel axis. The use of temperature fields is a versatile method to control the fluid flow. For this reason, we combine temperature fields generated by the Ohmic heating due to the electric field with external heating sources like Peltier elements and laser light. By these means, we are able to generate a directed net fluid flow but also highly complex streaming patterns. These streaming patterns can be used to mix tiny volumes in a laminar flow or to accumulate nanoparticles in stationary vortices.

CPP 20.8 Thu 12:00 ZEU 160

Lattice Boltzmann studies of chaotic flows in microchannels — •Fathollah Varnik and Dierk Raabe — MPI fuer Eisenforschung, Max-Planck Strasse 1, 40237 Duesseldorf

Via lattice Boltzmann simulations, it is shown that a qualitative change in flow properties may be triggered by a variation of the wall roughness/geometry alone. In particular, a transition from a steady flow toward an unsteady chaotic flow is observed as the roughnes height in increased in shark teeth channels. Similar observations are also made for a random distribution of obstacles along the channel underlining the generality of the observed transition.

We focus on the impact of various roughness parameters on the transition showing that it is not the roughness height alone which determines the onset of flow instability. Rather, it is the combined effect of the roughness height- and wave length which is essential. In particular, by an increase of the roughness wave length, it is possible to trigger flow instability even if the roughness height is reduced.

In view of increasing number of potential applications of chaotic flows in civil engineering, environmental industry (e.g. solution recovery) as well as in the medical science (e.g. enhanced chaotic mixing in microchannels), the results of our studies may find a wide range of applications as they open an alternative way for tuning flow properties, namely via an appropriate channel design.

CPP 20.9 Thu 12:15 ZEU 160

Vibration dynamics of a bubbly fluid in a channel — •Arthur Straube[1] and Sergey Shklyaev[2] — [1]University of Potsdam, Am Neuen Palais 10, PF 601553, D-14415 Potsdam — [2]Department of Mathematics, Technion – Israel Institute of Technology, 32000 Haifa, Israel

We study the behavior of a bubbly fluid in a long channel subjected to small amplitude, high frequency oscillation. Bubbly medium dynamics is described in terms of an averaged model [1]. Evolution of a quiescent liquid with the uniform distribution of bubbles in the channel subjected to transversal vibration is chosen as the initial state. It is demonstrated that the behavior of small bubbles in the channel can be controlled: depending on the vibration frequency, bubbles either migrate to the boundaries of the layer or accumulate into one or more steady stripes parallel to the boundaries; the characteristic width of the stripes depends on the diffusion of the bubbles. We perform a linear stability analysis and prove that such structures are stable up to some critical intensity of vibration action. To understand the dynamics of the system beyond this threshold the full nonlinear system is analyzed numerically.

[1] A.V. Straube, D.V. Lyubimov, S.V. Shklyaev, Averaged dynamics of two-phase media in a vibration field, submitted to Phys. Fluids.