CPP 46: Micro- and Nanofluidics II

Time: Friday 10:30–13:00 Location: ZEU 222

Topical Talk CPP 46.1 Fri 10:30 ZEU 222
Droplet-based microfluidics and the dynamics of emulsions — •Jean-Christophe Baret — Max-Planck Institute for Dynamics and Self-organization

Emulsions are complex fluids already involved for a long time in a wide-range of industrial processes, such as, for example, food, cosmetics or materials synthesis [1]. More recently, applications of emulsions have been extended to new fields like biotechnology or biochemistry where the compartmentalization of compounds in emulsion droplets is used to parallelize (bio-)chemical reactions [2,3]. Interestingly, these applications pinpoint to fundamental questions dealing with surfactant dynamics, dynamic surface tension, hydrodynamic interactions and electro-hydrodynamics. Droplet-based microfluidics is a very powerful tool to quantitatively study the dynamics of emulsions at the single droplet level or even at the single interface level: well-controlled emulsions are produced and manipulated using hydrodynamics, electrical forces, optical actuation and combination of these effects. We will describe here how droplet-based microfluidics is used to extract quantitative informations on the physical-chemistry of emulsions for a better understanding and control of the dynamics of these systems.

[1] J. Bibette et al. Rep. Prog. Phys., 62(6), 969-1033 (1999) [2] A.D. Griffiths and D. Tawfik, Trends in Biotechnology, 24(9), 395-402 (2006) [3] J.-C. Baret et al. Chem. Biol., 17(5), 528-536 (2010)

CPP 46.2 Fri 11:00 ZEU 222
Structural Transitions in a Two-Dimensional Microfluidic Crystal — •Jean-Baptiste Fleury[1], Ohle Caussen[2], Stephan Herminghaus[2], Martin Brinkmann[2], and Ralf Seemann[1,2] — [1]Saarland University, Saarbrücken, Germany — [2]Max Planck Institute for dynamic and Self-Organization, Goettingen, Germany

To understand the fundamental principles of droplet packing and manipulation in microfluidic channels we explore the static arrangement of a train of monodisperse water-in-oil emulsion droplets trapped in a straight, quasi two dimensional microfluidic channel with flat rectangular cross section. The length of the droplet train at constant droplet number can be varied by liquid plugs which act as two movable pistons. In this experimental setting we control the static compressive force applied by these plugs and allow the emulsion to mechanically equilibrate by an exchange of the continuous phase with a reservoir. As a result of the changing longitudinal confinement the droplets self-organize in different packing geometries, depending on their size, which can be distinguished by the topology of their contact network. These experimental results are in good quantitative agreement with our analytical calculations of the droplet arrangement, based on minimization of the interfacial energy. The theoretical predictions of droplet organization in different packing geometries also holds true when the structure is flowing in microfluidic channels. Indeed, these flowing structures self organize in periodic lattices that correspond to local minima of the relevant energy functional already discuss in the static case.

CPP 46.3 Fri 11:15 ZEU 222
Deformation of particle-stabilized droplets in multicomponent fluids — •Stefan Frijters and Jens Harting — Department of Applied Physics, Eindhoven University of Technology, Eindhoven, The Netherlands

Traditionally, enhanced oil recovery processes often employ surfactants to improve oil yield. In this project, nanoparticles are considered as an alternative to these surfactants. To determine in which ways these particles might be useful we need to understand how they modify the properties of a droplet of fluid suspended in another fluid. We present a simulation algorithm based on a multicomponent lattice Boltzmann model to describe the solvents combined with a molecular dynamics solver for the description of the solved particles. We have the ability to tune numerous relevant parameters of the system, such as particle sizes and wettability and surface tensions between the fluids and we use this ability to study the behaviour of fluid droplets stabilized by particles when subjected to shear. We then consider how these effects compare to those of surfactants.

CPP 46.4 Fri 11:30 ZEU 222
Influence of the solid/liquid interface on the flow dynamics of unentangled polymer melts — •Mischa Klos, Matthias Lessel, Oliver Bäumchen, and Karin Jacobs — Saarland University, Department of Experimental Physics, D-66041 Saarbrücken

Due to downsizing of microfluidic devices, the solid/liquid interface becomes more and more influential for liquid flow. In classic hydrodynamics, the velocity profile of a liquid flowing through a tube or over a surface extrapolates to zero close to a wall. By applying a hydrophobic coating to the solid surface it is possible to create a finite velocity of the liquid at the solid/liquid interface, known as slippage. Slippage is characterized by the extrapolation length of the flow profile, called slip length. In our experiments, liquid flow is induced by an internal driving force which drives the dewetting of thin polymer films on hydrophobic substrates. The slip length can be extracted by monitoring the dewetting dynamics of the emerging holes in the film or by characterizing the shape of the surrounding rim. Aside from the strong impact of inter-chain entanglements on slippage, also the type of hydrophobic substrate influences the slip length. We show results for thin polystyrene films flowing over an amorphous polymeric coating (AF1600) and different types of self-assembled monolayers of silanes. The AF1600 induces nearly no slip at the solid/liquid interface, in contrast to the silan surfaces, where the slip length reaches values from several hundreds of nanometers up to micrometers. We investigate whether slippage varies with the silane's chain length, its structure on the molecular level and the surface energy.

CPP 46.5 Fri 11:45 ZEU 222
Simulations of slip flow on rough and nanobubble-laden surfaces — •Jens Harting[1,2], Christian Kunert[2], and Jari Hyväluoma[3] — [1]Department of Applied Physics, Eindhoven University of Technology, Den Dolech 2, NL-5600MB Eindhoven, The Netherlands — [2]Institute for Computational Physics, University of Stuttgart, Pfaffenwaldring 27, D-70569 Stuttgart, Germany — [3]MTT Agrifood Research Finland, FI-31600 Jokioinen, Finland

On microstructured hydrophobic surfaces, geometrical patterns may lead to the appearance of a superhydrophobic state, where gas bubbles at the surface can have a strong impact on the fluid flow along such surfaces. In particular, they can strongly influence a detected slip at the surface. We present two-phase lattice Boltzmann simulations of a flow over structured surfaces with attached gas bubbles and demonstrate how the detected slip depends on the pattern geometry, the bulk pressure, or the shear rate. Further, we present recent results from the modeling of AFM based experiments for slip measurements and the investigation of fluid-surface interactions.

CPP 46.6 Fri 12:00 ZEU 222
Quantitative Analysis of Fluorescence Cross Correlation Spectroscopy Data for the Study of Hydrodynamics near Surfaces — Roman Schmitz[1], Stoyan Yordanov[1], Hans-Juergen Butt[1], Kaloian Koynov[1], and •Burkhard Duenweg[1,2] — [1]Max Planck Institute for Polymer Research, Mainz, Germany — [2]Dept. of Chemical Engineering, Monash University, Melbourne, Australia

We present a new method of data analysis for the interpretation of fluorescence cross correlation spectroscopy measurements in total internal reflection, from particles immersed in hydrodynamic flows near surfaces. Brownian Dynamics simulations are used to produce auto- and cross-correlation curves with defined input values of parameters like shear rate, slip length, particle diffusion constant, etc. These curves are directly compared with the corresponding experimental results. The optimum set of parameters, together with the corresponding set of their statistical errors, is the solution of a nonlinear fit problem, which is solved by an importance-sampling Monte Carlo procedure in parameter space. Substantial statistical effort in both the experiments and the numerics produces good agreement between experiment and theory, but also reveals subtle deficiencies in the underlying simulation model. Nevertheless, even the present simple model is already able to produce a fairly reliable bound on the slip length.

CPP 46.7 Fri 12:15 ZEU 222
Mesoscopic simulations of electroosmotic flow and electrophoresis in nanochannels — •Jens Smiatek[1] and Friederike Schmid[2] — [1]Institut für Physikalische Chemie, Westfälische Wilhelms-Universität Münster, D-48149 Münster, Germany — [2]Institut für Physik, Johannes Gutenberg-Universität, D-55099 Mainz,

Germany

We review recent dissipative particle dynamics (DPD) simulations of electrolyte flow in nanochannels. A method is presented by which the slip length δ at the channel boundaries can be tuned systematically from negative to infinity by introducing suitably adjusted wall-fluid friction forces. Using this method, we study electroosmotic flow (EOF) in nanochannels for varying surface slip conditions and fluids of different ionic strength. Analytic expressions for the flow profiles are derived from the Stokes equation, which are in good agreement with the numerical results. Finally, we investigate the influence of EOF on the effective mobility of polyelectrolytes in nanochannels. The relevant quantity characterizing the effect of slippage is found to be the dimensionless quantity $\kappa\delta$, where $1/\kappa$ is an effective electrostatic screening length at the channel boundaries.

CPP 46.8 Fri 12:30 ZEU 222

On the dissipation and oscillatory solvation forces in confined liquids — •Sissi de Beer[1], Wouter den Otter[2], Dirk van den Ende[1], Wim Briels[2], and Frieder Mugele[1] — [1]Physics of Complex Fluids, Twente University, Enschede, the Netherlands — [2]Computational BioPhysics, Twente University, Enschede, the Netherlands

Usually, a fluid is considered as a continuum medium characterized by a well-known density and viscosity. Upon miniaturization of (nano-) fluidic systems down to a height of only a few nanometer, however, the discrete molecular structure becomes visible and the liquid behaves completely different from the bulk. We study the dissipation in confined liquids and show via Atomic Force Microscope measurements and Molecular Dynamics simulations that the dissipation depends highly on the structure of the liquid molecules. When a discrete amount of molecular layers fit between the two confining surfaces the molecules are maximally organized and we find a minimum in the dissipation, while in between the dissipation significantly increases.

CPP 46.9 Fri 12:45 ZEU 222

Energetics of diffusiophoretic motion — •Benedikt Sabass and Udo Seifert — II Institut für Theoretische Physik, Universität Stuttgart, Germany

Small particles, in a viscous medium, propelled through an asymmetric distribution of solutes around them, can be employed for active transport or even as micromotors. For neutral solutes, this motion is termed diffusiophoresis. The asymmetry of solute concentration can be either produced by a chemical reaction on the particle surface (self-propelled swimmer) or it can be externally imposed. Here we discuss energetic aspects of diffusiophoresis [1]. We calculate the efficiency of a self-propelled swimmer in a true steady state for different reaction kinetics. The role of the hydrodynamic efficiency as upper bound to the overall efficiency is stressed. Further, we investigate the energy balance of quasi-stationary descriptions of diffusiophoresis in an externally imposed solute gradient, where the solute convection must be taken into account.

[1] B. Sabass and U. Seifert, Phys. Rev. Lett. 105, 218103 (2010)