DY 46: Poster: Wetting, Nano- and Microfluidics

Time: Wednesday 18:15–21:00 Location: Poster B2

DY 46.1 Wed 18:15 Poster B2

Theoretical study of slip effects on a dewetting drop — •Tak Shing Chan[1], Joshua D. McGraw[1,2], Thomas Salez[3], and Martin Brinkmann[1] — [1]Experimental Physics, Saarland University, D-66041, Saarbrücken, Germany — [2]Département de Physique, Ecole Normale Supérieure / PSL Research University, CNRS, 24 rue Lhomond, 75005 Paris, France — [3]PCT Lab, UMR Gulliver 7083, ESPCI ParisTech, PSL Research University, 75005 Paris, France

A recent experimental study on the dewetting of polymer microdroplets have shown that slip plays a dominating role on the shape evolution and the motion of the contact line (Under review). Particularly, a transient bump is observed for relatively small slip lengths, while a bump is avoided for larger values. In this theoretical study, we investigate the dewetting of a drop in a wider regime of parameter space. Using the boundary element method, we solve for the axisymmetric Stokes flow with i) the Navier-slip boundary condition at the solid/liquid boundary, and ii) a time-independent microscopic contact angle at the contact line position. We compute the profile evolution for different slip lengths and equilibrium contact angles. We find that when decreasing the slip length, the characteristic size of the bump first increases, and then decreases. More interestingly, the size of the bump even reaches zero, meaning no bump is observed, if the slip length is small enough. This remarkable result may indicate a crossover to the quasi-static regime when the slip length is very small.

DY 46.2 Wed 18:15 Poster B2

Inertial migration of elastic capsules in Poiseuille flow — •Christian Schaaf, Kevin Irmer, Christopher Prohm, and Holger Stark — Institut für Theoretische Physik, Technische Universität Berlin, Berlin

Deformable particles such as capsules, vesicles, and red blood cells assemble at fixed equilibrium positions in a microfluidic channel. This behavior can be used to separate particles with different cell properties. For example, softer cells travel closer to the center than stiffer ones.

Using the lattice-Boltzmann method, we study the dynamics of single deformable particles in a microfluidic channel for intermediate Reynolds numbers.

We show that particles move to different equilibrium position depending on their size and deformability. For Reynolds numbers below 100, their equilibrium positions collapse onto a single master curve depending only on the Laplace number. The steady state of the particles is determined by the lift force profiles, which we determine for different channel aspect ratios.

DY 46.3 Wed 18:15 Poster B2

Pairs of rigid particles in inertial microfluidics — •Felix Rühle, Christopher Prohm, and Holger Stark — Institut für Theoretische Physik, Technische Universität Berlin, D-10623 Berlin

We investigate rigid spherical particles in rectangular microchannels under the influence of Poiseuille flow at intermediate Reynolds numbers. It is well known that a single particle shows inertial focussing in this regime [1]. Furthermore, for rectangular channels with sufficiently large aspect ratio only two lateral equilibrium positions exist.

In this contribution we present first results on the behaviour of a particle pair in such a channel thus increasing the complexity of the one-particle system that has already been thoroughly examined [2]. An in-depth understanding of the multi-particle interactions will provide insights into the properties and dynamics of particle chains as well as the formation of so-called microfluidic crystals [3].

The particle pair is placed in the channel with variable axial distance and lateral positions. Inertial migration in the cross section of the channel is quantified by the lift force profile. We determine how it changes due to the presence of a neighboring particle. This helps us to explain the observed passing trajectories, where particles overtake each other, swapping trajectories, and damped oscillations. The latter involve both axial and lateral motion and occur when particles are on opposite sides of the channel centerline.

[1] G. Segré and A. Silberberg, *Nature* **189**, 209 (1961).
[2] C. Prohm and H. Stark, *Lab Chip* **14**, 2115 (2014).
[3] W. Lee et al., *PNAS* **107**, 22413 (2010).

DY 46.4 Wed 18:15 Poster B2

Super Liquid Repellency — •Frank Schellenberger, Jing Xie, Noemí Encinas, Maxime Paven, Doris Vollmer, and Hans-Jürgen Butt — Max Planck Institute for Polymer Research, Mainz, Germany

The Pandora box of surfaces able to repell liquids is still a hot research topic. These surfaces are able to remove dust (self-cleaning) and can even hinder the growth of microorganism colonies.

Over the past years we have created superhydrophobic coatings (water repellent) where water droplets sit on microscopic pockets of air, which are trapped beneath the liquid drops. We even designed superamphiphobic coatings (i.e. water and oil repellent). One of these types are the so called slippery surfaces, where after infusing a rough/porous structure with a lubricant a deposited drop will slip by tilting the surface by a few degrees. This pressure-stable omniphobicity opens exciting applications for anti-biofouling, anti-icing or anti-frost performances. However, the mechanism how a drop moves on slippery surfaces is still unclear.

In this case, we used Laser Scanning Confocal Microscopy (LSCM) to observe the contact angles and evaluate the dynamics of droplet motion on the microscale.

DY 46.5 Wed 18:15 Poster B2

Silica stabilized Pickering-emulsions for hydroformylation — •Judith Witte[1], Dmitrij Stehl[1], Regine von Klitzing[1], Tobias Pogrzeba[1], Marcel Schmidt[1], Reinhard Schomäker[1], Lena Hohl[2], Matthias Kraume[2], Tina Skale[3], and Anja Drews[3] — [1]TU-Berlin, Straße des 17. Juni 124, 10623 Berlin — [2]TU-Berlin, Frauenhoferstr. 33-36, 10587 Berlin — [3]HTW Berlin, Wilhelminenhofstr. 75 A, 12459 Berlin

Pickering-emulsions (PEs) are particle stabilized emulsions. PEs can be used for catalytic reactions, for example for the hydroformylation of long chained olefins in a water in oil (w/o-) emulsion. In this study, the water droplets (water phase) which are surrounded by SiO2-nanoparticles as stabilizer, contain [HRh(CO)(TPPTS)3] as homogeneous catalyst. The particle-stabilized water droplets are emulsified in 1-Dodecene (oil phase). After the hydroformylation, the water droplets with the expensive catalyst can be easily separated from the product by membrane filtration and used again for the next reactions. This is a huge advantage in comparison to surfactant stabilized emulsions, which often break during filtration processes. Preliminary experiments showed that an increase in the amount of SiO2-nanoparticles leads to an increase of the product yield (Tridecanal) and decreases the droplet size from 0.02 to 0.005 mm. An addition of surfactant (Triton X-100) at low concentrations (<cmc) increases the product yield as well.

DY 46.6 Wed 18:15 Poster B2

Contact Line Dynamics and Hydrodynamic Boundary Conditions in Stepped Liquid Films — •Marco Rivetti[1], Thomas Salez[2], Michael Benzaquen[2], Elie Raphaël[2], and Oliver Bäumchen[1] — [1]Max Planck Institute for Dynamics and Self-Organization (MPIDS), Göttingen, Germany — [2]UMR Gulliver, CNRS and ESPCI ParisTech, PSL University, Paris, France

For flows on the micro- and nanoscale, the physics of the contact line as well as the hydrodynamic boundary condition at a solid surface play a crucial role. In past few years much has been learned about both phenomena from flows that are driven by capillary forces. We here discuss some recent results involving thin liquid films which exhibit slip or no-slip boundary conditions. In the absence of slip, the relaxation of a liquid nanostripe on a smooth, hydrophilic substrate has evidenced the occurrence of, both, stationary and receding contact line regimes [1]. Self-similarity of the liquid profiles in the stationary regime has been proved, and a universal transition between the two regimes has emerged by rescaling with regard to the viscosity, surface tension and film thickness. In the second part we discuss the relaxation of initially perturbed liquid surfaces [2], i.e. stepped liquid films in the absence of contact lines. We find strong evidence that this relaxation process is also sensitive to the slip boundary condition at the solid/liquid interface. Thin film models comprising slip enable a quantification of the slip length of viscous liquids of various molecular properties. [1] Rivetti et al., Soft Matter 11 (2015) [2] McGraw et al., Phys. Rev. Lett. 109, 128303 (2012)

DY 46.7 Wed 18:15 Poster B2

Fluid invasion in porous media: front morphology, residual saturation, and the Cieplak-Robbins-transition — •Stephan Herminghaus[1], Ralf Seemann[2], Kamaljit Singh[2], Hagen Scholl[2], Marco Di Michiel[3], and Mario Scheel[3] — [1]MPI für Dynamik und Selbstorganisation, Göttingen — [2]Fakultät für Physik, Universität des Saarlandes, Saarbrücken — [3]ESRF, Grenoble

The fluid front morphologies emerging during fluid invasion into random piles of spherical beads are investigated in real time by X-ray micro-tomography and analyzed theoretically. Depending on the wettability of the invaded medium, we observe two distinct displacement regimes exhibiting strongly different liquid front morphologies. These regimes are separated by a pronounced transition, at which the residual saturation of the defending liquid (RSD) changes abruptly by one order of magnitude. We show that the critical contact angle at which this transition takes place can be quantitatively predicted on the basis of a quasi-static consideration of the wetting geometry of the progressing front. Furthermore, we find that the RSD agrees, within experimental scattering, quantitatively with our predictions from analytical theory, without invoking any fitting parameter.

DY 46.8 Wed 18:15 Poster B2

Particle Confinement by Marangoni Convection in Microchannels — •Michael Orlishausen, Lorenz Butzhammer, and Werner Köhler — Physikalisches Institut, Universität Bayreuth, Universitätsstr. 30 95447 Bayreuth

We have investigated the flow of unary and binary liquids near a liquid-gas interface in a mirochannel device due to Marangoni Convection caused by a gradient in temperature and concentration (in the case of the binary liquids). By using latex microparticles of 1*m diameter we were able to visualize the resulting currents through optical microscopy. Depending on the position of the meniscus in the microchannel and other factors, one or two convection rolls appear. Surprisingly, however, the particles are confined to certain streamlines and regions in the microchannel and characteristic depletion zones form around them. In order to explain the origin of this observation we have performed finite elements simulations to the flow in the microchannel and identified the outermost streamline containing particles as being connected to the minimum distance to the meniscus one of those particles can take up. Additionally, we have investigated the influence of diffusion on particles in such a flow by means of Langevin simulations. The counter-intuitive result is an enhanced particle confinement caused by particle diffusion between different streamlines.

DY 46.9 Wed 18:15 Poster B2

Onset of motion of a sliding droplet — Simeon Völkel and •Kai Huang — Experimentalphysik V, Universität Bayreuth, 95440 Bayreuth, Germany

We investigate experimentally the onset of motion of a water drop on an inclined plane with contact angle hysteresis. The onset of motion is triggered either through increasing the volume of the drop with an inkjet printer head or through tilting the plane with a stepper motor. Based on an analysis of both top view and side view images, we explore the evolution of the drop shape with time in the vicinity of the depinning transition and discuss how different ways to trigger the motion influence the bifurcation scenario of the transition. Finally, we analyze the eccentricity of the drop as a function of bond number that measures the ratio of gravitational forces to surface tension forces and compare our results with numerical simulations.

DY 46.10 Wed 18:15 Poster B2

Mechanical properties of highly porous super liquid-repellent surfaces — •Maxime Paven, Regina Fuchs, Doris Vollmer, Michael Kappl, and Hans-Jürgen Butt — Max Planck Institute for Polymer Research, Ackermannweg 10, 55128 Mainz, Germany

The poor mechanical properties of highly porous materials restrict their utilization for a wide range of applications such as light weighted, insulating or super liquid-repellent coatings. Especially, the design principles of super liquid-repellent surfaces aim at maximizing roughness at the nano or micrometer scale, making them inherently mechanically weak. To find a balance between repellency and stability investigation of the surfaces*s mechanical properties is essential. Here, we use atomic force microscopy, colloidal probe, nanoindentation, and pencil scratching to investigate the mechanical properties of super liquid-repellent surfaces prepared by soot templating. We varied the reaction paramteres, i.e. the thickness of the template-stabilizing silica shell and the sintering temperature to investigate their influence on the wetting and mechanical properties. Sintering at 1000 °C increased the effective elastic modulus of the surface by more than an order of magnitude. Sintering at 1150 °C led to a smoothening of the porous silica network and the effective elastic modulus increased by up to five orders of magnitude. At the same time, however, for droplets of n-hexadecane the roll-off angle increased and the receding contact angle decreased. This emphasizes the delicate balance of stability and repellency for super liquid-repellent surfaces.

DY 46.11 Wed 18:15 Poster B2

Geometry induced asymmetric contact angles — •Bang-Yan Liu — National Taiwan University, Department of Chemical Engineering, 10617 Taipei, Taiwan — Saarland University, Experimental Physics, D-66041 Saarbrücken, Germany

Triangle post decorated surfaces were studied in this research. Triangular posts were arranged in square lattice and made from PDMS. Asymmetric contact angles were observed, both advancing and receding contact angle in triangle base direction were higher than that in the tip direction. Structures with various triangle sizes and post heights were examined and the three-phase contact line motion was analyzed to study this phenomenon. As water spreading, a strong pinning always happened on the outermost edges of triangular post structure related to droplet center, and with the increase of structure edge presence in three-phase contact line, advancing contact angle raised dramatically. The geometry difference of triangle tip and base resulted in different edge presence of three-phase contact line and caused contact angle asymmetry. However, when the structure height grew, advancing contact angle of both directions increased, and the asymmetry was reduced. On the other hand, de-wetting showed different behavior. Three-phase contact line pinned on the inner edge of structure and one-by-one depinning behavior was observed. Receding contact angle happened when the retreating three-phase contact line depinned from the very last structures to another row of structures. By designing and tuning structure geometry, an easy-produced asymmetry surface can be obtained.

DY 46.12 Wed 18:15 Poster B2

Wetting Characteristics in Bidisperse Sphere Packings — •Robabeh Moosavi[1], Julie Murison[2], Martin Brinkmann[1,3], and Matthias Schröter[1] — [1]Max-Planck Institute of Dynamics and Self-Organization, Göttingen, Germany — [2]Clariant Produkte GmbH, Competence Center Interface and Formulation Technology, Frankfurt, Germany — [3]Universität des Saarlandes, Saarbrücken, Germany

We report experiments on liquid two-phase flow in bidisperse sphere packings consisting of small and large beads which are either oil wetting or water wetting. Aim of our work is to understand the parameters determining the average wettability of these samples and their residual oil saturation after the packing was invaded by water. The former is studied by measuring the capillary pressure saturation curves [1], the latter by imaging the samples with X-ray tomography. We find that mixed wet samples show a smaller dissipation during a complete drainage/imbibition cycle than when the sample is composed of beads of one type of wetting behavior.

[1] Murison et al., *Phys. Rev. Appl.* **2014**, 2, 034002

DY 46.13 Wed 18:15 Poster B2

Wettability controls immiscible fluid displacement through local interfacial instabilities — Micheal Jung[1], Martin Brinkmann[1,2], Marta Sanchez de La Lama[2], Thomas Hiller[2], Stephan Herminghaus[2], and •Ralf Seemann[1] — [1]Experimental Physics, Saarland University, Saarbrücken — [2]Max Planck Institute for Dynamics and Self-Organisation

Slow immiscible fluid displacement is studied in a transparent quasi two-dimensional Hele-Shaw cell with cylindrical posts for different wetting conditions of the invading fluid. Employing various combinations of fluids and cell materials allows to cover a range of advancing contact angles θ_a of the invading fluid between 46° and 180° in our experiments. In parallel, we performed numerical simulations of the displacement process employing a particle-based method that accounts for wall wettability in the same arrangements of cylindrical posts as in experiments. A cross-over between capillary fingering at high values of $\theta_a \gtrsim 120°$ and stable interfacial displacement at $\theta_a \lesssim 80°$ is observed in experiments and simulations, and quantified through the front length and the final saturation of the displaced fluid. Analysis of the local displacement processes in experiments and simulations demonstrate that the evolution of the front shape is governed by the local advancing modes for quasi-static interfacial displacement as proposed by Cieplak and Robbins [Phys. Rev. Lett. **60** (1988)]. A comparison of the relative frequency of certain advancing modes reveals a cross-over between cooperative interfacial instabilities for good wetting conditions and non-cooperative instabilities for poor wetting conditions.

DY 46.14 Wed 18:15 Poster B2

Wetting properties of n-alkane nanostructures — •Diego Diaz[1], Tomas Corrales[2], Maria Retamal[1,3], Marcelo Cisternas[1], Patrick Huber[4], and Ulrich Volkmann[1] — [1]Centro de Investigación en Nanotecnología y Materiales Avanzados, CIEN-UC, Pontificia Universidad Católica de Chile, Santiago, Chile — [2]Instituto de Alta Investigación, Universidad de Tarapacá, Arica, Chile — [3]Facultad de Química, Pontificia Universidad Católica de Chile, Santiago, Chile — [4]Materials Physics, Hamburg U. of Technology, D-21073 Hamburg, Germany

Recently, we have shown that it is possible to modify the surface coverage and morphology of an n-alkane molecular layer over silicon by controlling the withdrawal velocity of the substrate from solution (T.P. Corrales et al., ACS Nano 8, 9954-9963, 2014). As a follow-up work, we study here the wetting properties of silicon surfaces coated with molecular layers of n-alkane as a function of the surface coverage and morphology, using a drop shape analysis procedure. We have found from our measurements that both the coverage and morphology of the underlying nanostructures affects the contact angle of the surface. In particular, stripe-like structures present lower contact angles than dendritic structures that have roughly the same coverage and thickness. All films consist of a single n-alkane molecular layer with a height of around 5 nm. Furthermore, we find differences in the contact angles measured parallel and perpendicular to the withdrawal direction of the substrate from solution.