

CPP 62: Fluids and Interfaces III

Time: Thursday 15:00–18:15

Location: ZEU 255

CPP 62.1 Thu 15:00 ZEU 255

Wedge wetting by an electrolyte solution — ●MAXIMILIAN MUSSOTTER and MARKUS BIER — Max Planck Institute Int. Sys. and University of Stuttgart, Germany

Wetting of substrates by fluids is a phenomenon of enormous importance in nature and technology. Whereas the highly idealised set-up of flat substrates in contact with simple fluids has been addressed intensively in the past, there is a huge practical interest in more realistic, and typically more complex, situations. A rather simple deviation from a flat substrate is a wedge-shaped wall, whose wetting properties by simple fluids have been studied for decades. An important phenomenon occurring in that context is the filling of a wedge, pre-empting the wetting transition of a planar wall.

Here, as a step towards more realistic set-ups, the wetting of a wedge by an electrolyte solution is considered, because many real fluids contain ions and electrostatic effects typically play a dominating role in the structure formation. One of the most remarkable findings of our study is the change of the order of the filling transition from a continuous transition for small surface charge densities to a first-order transition for large surface charge densities.

CPP 62.2 Thu 15:15 ZEU 255

Wetting over pre-existing liquid films - a tsunami on microscale — ●HANNU TEISALA, ANKE KALTBEITZEL, WERNER STEFFEN, HANS-JÜRGEN BUTT, and DORIS VOLLMER — Max Planck Institute for Polymer Research, Ackermannweg 10, 55128 Mainz, Germany

Wetting of solids by liquids is a ubiquitous phenomenon of our everyday life. It is of utmost importance in several industrial operations including variety of coating applications, self-cleaning, oil recovery, heat transfer, and water harvesting from humid air. Static wetting situations, where the surface tension forces, γ , between solid, liquid, and gas phases balance with gravity leading to an energetically favored equilibrium state, are rather well understood. Comprehension of dynamic wetting situations, which are more common in real environment, is a challenge. Especially, wetting over pre-existing liquid films and the hydrodynamics within menisci - which are determined by the interplay of surface tension forces, gravity, and viscous stresses within the liquid - are poorly understood. Here we show how negative Laplace pressure acting at the meniscus of silicone oil, a common lubricant, induces a strong capillary suction that dominates the interface curvature and hydrodynamics when the meniscus is resting on or advancing over a thin film of the same liquid. The drastic consequences of negative Laplace pressure in wetting over liquid films have not been recognized earlier. Our findings add knowledge in the field of wetting and contribute to resolving generic issues such as homogeneous film formation in coating and meniscus formation, its hydrodynamics, and depletion of lubricant on slippery, lubricated surfaces.

CPP 62.3 Thu 15:30 ZEU 255

Comparing models of electrolyte solutions at curved electrodes — ●ANDREAS REINDL, MARKUS BIER, and SIEGFRIED DIETRICH — Max Planck Institute for Intelligent Systems, Stuttgart, Germany

The proper functioning of many natural and artificial systems relies on an electrically charged substrate in contact with an electrolyte solution. As real substrates are typically rough, one has to reckon with properties deviating from those of idealised models based on smooth planar walls. In the present study we consider electrolyte solutions in contact with curved electrodes of spherical and cylindrical shape. Whereas these types of wall shapes have been investigated already in the past, the previous studies concentrated on specific models, without comparing different levels of sophistication. Here a variety of models within density functional theory are applied in order to describe the structure of the electrolyte solutions, and the differential capacitance was chosen as the central observable to characterise the electrical double layer. This procedure facilitates to compare results of different model calculations as a function of the electrode curvature. The mesoscopic Poisson-Boltzmann description allows for a detailed analysis and can be used as a gauge for more complex models. Within the so-called civilized model microscopic details such as particle volumes and solvent molecules with embedded dipole moments are taken into account. The influence of these microscopic parameters can be judged in comparison

with simpler models.

Reference: A. Reindl, M. Bier, and S. Dietrich, in preparation.

CPP 62.4 Thu 15:45 ZEU 255

Influence of surfactants in forced dynamic dewetting — ●GÜNTER. K. AUERNHAMMER, FRANZISKA HENRICH, DANIELA FELL, DOROTA LINKE, and HANS-JÜRGEN BUTT — MPI Polymer Research, Mainz, Germany

In this work we show that the forced dynamic dewetting of surfactant solutions depends sensitively on the surfactant concentration. Anionic, cationic and nonionic surfactants with critical micelle concentrations (CMCs) spanning four orders of magnitude were used. The receding contact angle in water decreased with increasing velocity. This decrease was strongly enhanced when adding surfactant, even at surfactant concentrations of 10% of the critical micelle concentration (1). Plots of the receding contact angle- versus-velocity almost superimpose when being plotted at the same relative concentration (concentration/CMC). Thus the rescaled concentration is the dominating property for dynamic dewetting. The charge of the surfactants did not play a role, excluding electrostatic effects. The change in contact angle can be interpreted by local surface tension gradients, i.e. Marangoni stresses, close to the three-phase contact line. The decrease of dynamic contact angles with velocity follows two regimes. Despite the existence of Marangoni stresses close to the contact line, for a dewetting velocity above 1–10 mm s⁻¹ the hydrodynamic theory is able to describe the experimental results for all surfactant concentrations. Flow profiles at different length scales support the hydrodynamic interpretation of the governing mechanism.

(1) F. Henrich, et al. *Soft Matter* **12** (2016): 7782 - 7791.

CPP 62.5 Thu 16:00 ZEU 255

Elasto-Capillary Interactions in the Absence of a Contact Line — MARCO RIVETTI¹, THOMAS SALEZ², MAXENCE ARUTKIN², CHUNG-YUEN HUI³, ELIE RAPHAEL², and ●OLIVER BÄUMCHEN¹ — ¹Max Planck Institute for Dynamics and Self-Organization (MPIDS), D-37077 Göttingen, Germany — ²UMR Gulliver, CNRS and ESPCI ParisTech, PSL University, Paris, France — ³Department of Mechanical and Aerospace Engineering, Cornell University, Ithaca, NY, USA

A thin liquid film with non-zero curvature at its free surface spontaneously relaxes towards a flat configuration. This flow is driven by Laplace pressure gradients and resisted by the liquid's viscosity. In the last few years, we have studied the dynamics of this system experimentally, numerically and analytically (e.g. Rivetti et al., *Soft Matter* **11**, 2015, McGraw et al., *PRL* **109**, 2012). Inspired by recent progresses on the wetting behaviour and the dynamics of liquid droplets on soft substrates, we here consider the relaxation of a thin viscous film supported by an elastic foundation. We present experiments involving thin PS films on PDMS substrates, where the dynamics of the liquid-air interface is monitored by AFM. In this system, Laplace pressure gradients not only drive the flow, but they also induce elastic deformations on the substrate. These deformations affect the flow and the shape of the liquid-air interface itself, giving rise to an original example of an elasto-capillary interaction that is not mediated by the presence of a contact line. We also discuss a theoretical model and simulations that describe the coupled evolution of the substrate-liquid and the liquid-air interface.

CPP 62.6 Thu 16:15 ZEU 255

Wettability characteristics in fractionally wet porous media: a variation of the Cieplak-Robbins model — ●WEIWEI LI^{1,2}, MARTIN BRINKMANN^{1,2}, MICHAEL JUNG^{1,2}, STEPHAN HERMINGHAUS², and RALF SEEMANN^{1,2} — ¹Universität des Saarlandes, Saarbrücken, Germany — ²Max Planck-Institute for Dynamics and Self-Organization, Göttingen, Germany

An extended two-dimensional model based on the seminal work of Cieplak and Robbins is developed to study the role that wettability plays in slow immiscible fluid displacement. The porous media in this model consists of two-dimensional disks, and the emerging series of local interfacial instabilities is controlled by the Laplace pressure, that drives the quasi-static motion of liquid fronts. Unlike the original CR model, we respect the possibility of advancing or retracting interfaces during periodic changes of the Laplace pressure. This variation of CR

model allows us to study capillary saturation characteristics in fractionally wet disk packs. Different statistical processes are applied to generate bidisperse disk packs with positional disorder. The simulations for a drainage-imbibition cycle reveal that there is a minimum hysteresis loop opening in fractionally wet packs. Several potential explanations are examined and discarded, favoring a simple explanation in terms of the distribution of entry pressures for non-cooperative pore filling events.

15 min break

CPP 62.7 Thu 16:45 ZEU 255

Structural disjoining pressures from DFT and the spreading of terraced drops — ●UWE THIELE¹, ADAM P. HUGHES², HANYU YIN², DAVID N. SIBLEY², and ANDREW J. ARCHER² — ¹Institut für Theoretische Physik, Westfälische Wilhelms-Universität, Wilhelm-Klemm Str. 9, 48149 Münster — ²Department of Mathematical Science, Loughborough University, Loughborough, LE11 3TU, UK

For a liquid film on a solid substrate, we determine the binding potential $g(h)$ that encodes the wetting behaviour. The method developed in [1] for the example of a simple discrete lattice-gas model, is used with continuum density functional theory (DFT) to calculate the binding potential for a Lennard-Jones fluid and other simple liquids. The DFT we use incorporates the influence of the layered packing of molecules at the surface. At low temperatures this can result in an oscillatory decay of $g(h)$, i.e., a structural disjoining pressure $\Pi = -\partial g/\partial h$ [2]. The obtained binding potentials are incorporated in a mesoscopic hydrodynamic model to study the spreading of (terraced) drops on both, an adsorption (or precursor) layer and completely dry substrates [3]. To achieve this, the thin film model is modified in such a way that for thicker films the standard mesoscopic hydrodynamic theory is realised, but for very thin layers a diffusion equation is recovered. [1] A.P. Hughes, U. Thiele, and A.J. Archer, *J. Chem. Phys.* 142, 074702 (2015). [2] A.P. Hughes, U. Thiele and A.J. Archer, preprint at <http://arxiv.org/abs/1611.06957>. [3] H. Yin, D.N. Sibley, U. Thiele and A.J. Archer, preprint at <http://arxiv.org/abs/1611.00390>.

CPP 62.8 Thu 17:00 ZEU 255

Effects of thermal fluctuations on an interface near a contact line — DANIELE BELARDINELLI¹, MAURO SBRAGAGLIA¹, ●MARKUS GROSS^{2,3}, and BRUNO ANDREOTTI⁴ — ¹Department of Physics & INFN, University of Rome "Tor Vergata", Via della Ricerca Scientifica 1, 00133, Rome, Italy — ²Max-Planck-Institut für Intelligente Systeme, Heisenbergstr. 3, 70569 Stuttgart, Germany — ³IV. Institut für Theoretische Physik, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — ⁴Physique et Mécanique des Milieux Hétérogènes, UMR 7636 ESPCI-CNRS, Université Paris-Diderot, 10 rue Vauquelin, 75005, Paris, France

We analytically study a liquid interface contacting a solid wall in the presence of interfacial and contact point fluctuations. A path integral description based on a contact potential is developed which takes fully into account the impenetrability of the wall. We do not assume the presence of a precursor film in front of the effective contact point, but, instead, treat the fluctuations of the contact point explicitly. As a consequence of entropic repulsion, the average profile is curved and a characteristic length scale given by the interfacial roughness emerges. The effect of fluctuations are captured in terms of an effective disjoining pressure. We identify a transition from a partial to a pseudo-partial wetting state, the latter being characterized by a precursor film of constant thickness. In the partial wetting state, instead, we find that the average profile is exponentially decaying in front of the mean contact point. Reference: D. Belardinelli, M. Sbragaglia, M. Gross, B. Andreotti, *Phys. Rev. E* 94, 052803 (2016)

CPP 62.9 Thu 17:15 ZEU 255

Aubry Transition in 2D Colloidal Crystals — ●THORSTEN BRAZDA — 2. Physikalisches Institut, Universität Stuttgart Pfaffenwaldring 57, 70550 Stuttgart, Germany

According to Aubry et al., the static friction of a monolayer of interacting particles sliding across a crystalline surface can completely vanish in incommensurate systems leading to superlubricity [1]. For a given amplitude of the substrate potential, there exists a critical value of the particle interaction strength above which the monolayer elastically slides across the substrate even for an infinitesimally small driving force. Below that value, the chain becomes locked to the substrate which leads to a finite static friction force. In our experiments

we investigate an extended 2D colloidal crystal which is driven across a (111) substrate, the latter created by a laser interference pattern. When the lattice constant of the colloidal crystal is incommensurate with the length scale of the underlying substrate potential, we observe the disappearance of static friction for non-zero substrate strengths. In agreement with recent numerical simulations [2], our results suggest, that this Aubry transition is of first order and that this dynamical phase transition is accompanied by characteristic structural changes in the monolayer.

1. M. Peyrard, *J. Phys. Chem. C: Solid State Physics*, 1983. 16(9): p. 1593.

2. D. Mandelli, *Physical Review B*, 2015. 92(13): p. 134306.

CPP 62.10 Thu 17:30 ZEU 255

Spontaneous electrification of fluoropolymer-water interfaces probed by electrowetting — ARUN BANPURKAR^{1,2}, YOGESH SAWANE¹, SANDIP WADHAI^{1,2}, CHANDRA MURADE², IGOR SIRETANU², DIRK VAN DEN ENDE², and ●FRIEDER MUGELE² — ¹Pune University, Pune, India — ²Univ. of Twente, Enschede, The Netherlands

Fluoropolymers are widely used as coatings for their robustness, water-repellence, and chemical inertness. In contact with water, they assume a negative surface charge, which is commonly attributed to adsorbed hydroxyl ions. Here, we demonstrate that a small fraction of these ions permanently sticks to Teflon AF and Cytop surfaces upon prolonged exposure to water. Electrowetting measurements carried out after aging in water are used to quantify the density of trapped charge. Values up to -0.07 and -0.2mC/m^2 are found for Teflon AF and for Cytop, respectively, at elevated pH. A similar charge trapping process is also observed upon aging in various non-aqueous polar liquids and in humid air. A careful analysis highlights the complementary nature of electrowetting and streaming potential measurements in quantifying interfacial energy and charge density. We discuss possible mechanism of charge trapping and highlight the relevance of molecular scale processes for the long term stability and performance of fluoropolymer materials for applications in electrowetting and elsewhere.

CPP 62.11 Thu 17:45 ZEU 255

Mesoscopic simulations of electrokinetic phenomena: electrowetting dynamics. — ●NICOLAS RIVAS¹, STEFAN FRIJTERS², IGNACIO PAGONABARRAGA³, and JENS HARTING^{1,2} — ¹Forschungszentrum Jülich GmbH, Helmholtz Institute Erlangen-Nürnberg for Renewable Energy (IEK-11), Nürnberg, Germany — ²Department of Applied Physics, Eindhoven University of Technology, Eindhoven, The Netherlands. — ³Departament de Física Fonamental, Universitat de Barcelona, Barcelona, Spain

Electrokinetic effects play a crucial role in many natural and technological systems, from the biological to nano-fluidics. Numerical simulations of conducting fluids present a significant challenge mainly due to the variety of length-scales involved, and the presence of two long-range interactions: hydrodynamic and electrostatic. We show an electrohydrodynamic mesoscopic model, discuss its validity, and focus on the electrowetting effect, where a droplet changes its contact angle with a substrate when an electric field is applied. The hydrodynamics of two fluids is solved using the lattice-Boltzmann method. Ions present in the solvents are considered at the level of the Nernst-Planck equation, which is solved via a finite-volume, finite-difference discretization, following the link-flux method. We show that the simulation scheme is robust and remains valid in a wide range of parameters. Furthermore, the model is able to quantitatively capture the electrowetting effect, and allows to study in detail the mechanisms that lead to the saturation of the contact angle.

CPP 62.12 Thu 18:00 ZEU 255

Jumping drops on superhydrophobic surfaces: controlling energy transfer by timed electric actuation — ZHANTAO WANG, ●DIRK VAN DEN ENDE, ARJEN PIT, RUDY LAGRAAUW, DANIEL WIJNPERLE, and FRIEDER MUGELE — Univ. of Twente, Enschede, The Netherlands

Aqueous sessile drops are launched from a superhydrophobic surface by electric actuation in an electrowetting configuration with voltage pulses of variable duration. We show that the jump height, i.e. the amount of energy that is transferred from surface energy to the translational degree of freedom, depends not only on the applied voltage but also in a periodic manner on the duration of the actuation pulse. The jump height for a pulse of optimized duration is almost twice as high as the one obtained upon suddenly turning off the voltage after equilibrating the drop under voltage. Representing the drop as a simple oscillator,

we show that optimum pulse duration is related to the eigenfrequency of the drop. From a general perspective, our experiments illustrate a generic concept to manipulate drops on functionalized surfaces by

tuning the duration of actuation stimuli to the intrinsic dynamics of the drops such that they can be positioned in a controlled manner in different non-equilibrium configurations.