

DY 52: Focus Session: Wetting on Adaptive Substrates III (joint session CPP/DY/O)

The focus session aims to discuss recent developments in the wetting dynamics of adaptive, deformable, and switchable surfaces.

Time: Friday 9:30–12:45

Location: H 0110

Invited Talk

DY 52.1 Fri 9:30 H 0110

Condensation on soft substrates — ●AMBRE BOUILLANT^{1,3}, BRUNO ANDREOTTI², and JACCO H. SNOEIJER³ — ¹Laboratoire MSC, CNRS UMR 7057, Université Paris Cité, FR — ²Laboratoire LPENS, CNRS UMR 8023, Université PSL, FR — ³Physics of Fluids, Twente University, NL

Vapor molecules can nucleate on cool substrates, provided the surrounding humidity is high enough. Dew formation has been investigated on both rigid (and rough!) solids as well as on liquids. However, how substrate elasticity affects the condensation process remains elusive. In this talk, I will present how water condenses on soft, elastic gels that are smooth at the nanometer scale. We prepare PDMS gels whose softness varies between that of a rigid substrate and an un-crosslinked polymeric liquid.

Although elasticity should be marginal at the nanometric scale at which drops form, we report that the nuclei density is highly sensitive to the substrate softness. Throughout this talk, I will delve into the intricate dynamics of condensation and try to explain some of the intriguing characteristics we have observed. Among these are the influence of softness on nucleation; the sub-diffusive growth of droplets; and the absence of secondary nucleation events (unlike what is classically observed in heterogeneous nucleation). Later, when neighboring drops get closer, they attract each other due to interactions mediated by substrate deformations. Drops then gather into clusters that seem reluctant to coalesce. This ultimately results in the formation of a persistent, ordered, honeycomb-patterned liquid film.

DY 52.2 Fri 10:00 H 0110

Modelling droplets on substrates with travelling-wave deformations — ●JOSUA GRAWITTER and HOLGER STARK — Technische Universität Berlin, Institut für Theoretische Physik, Hardenbergstr. 36, 10623 Berlin, Germany

Motivated by strategies for targeted microfluidic transport of droplets, we investigate how sessile droplets can be steered toward a preferred direction using travelling-wave deformations of the substrate. To perform our numerical study, we develop a formalism to apply the boundary-element method to dynamic wetting. It solves the governing Stokes equations for the fluid flow field inside the droplet that is pushed forward by the deforming substrate.

We find two distinct modes of droplet motion. For small wave speed the droplet surfs with a constant velocity on the wave, while beyond a critical wave speed a periodic wobbling motion occurs, the period of which diverges at the transition. In the related case of a flat substrate with travelling waves in wettability, such an observation is well rationalized by the *nonuniform oscillator* model and the transition described by a SNIPER bifurcation. Here, however, the mean droplet velocity in the wobbling state is proportional to the wave speed at large speed values since the droplet always has to move up and down. To rationalize this behavior, the nonuniform oscillator model has to be extended. Since the critical wave speed of the bifurcation depends on the droplet radius, this dependence can be used to sort droplets by size.

DY 52.3 Fri 10:15 H 0110

High Voltages Generated by Moving Water Drops — ●STEFAN WEBER^{1,2}, PRAVASH BISTA², AARON RATSCHOW³, and HANS-JÜRGEN BUTT² — ¹Institute for Photovoltaics, University of Stuttgart — ²MPI for Polymer Research, Mainz — ³Institute for Nano- and Microfluidics, TU Darmstadt

Water drops on insulating, hydrophobic substrates can generate electric potentials of kilovolts upon sliding for a few centimeters. We show that the drop saturation voltage corresponds to an amplified value of the solid-liquid surface potential at the substrate. The amplification is given by the substrate geometry, the drop and substrate dielectric properties and the Debye length within the liquid. Next to enabling an easy and low-cost way to measure surface- and Zeta potentials, the high drop voltages have implications for energy harvesting, droplet microfluidics and electrostatic discharge protection.

DY 52.4 Fri 10:30 H 0110

Electro(de)wetting with Photoswitches: Control of wetting by electric fields and light — ●BILLURA SHAKHAYEVA and BJÖRN BRAUNSCHWEIG — University of Münster, Institute of Physical Chemistry, 48149 Münster, Germany

Electro-dewetting (EDeW) was introduced as a new method in order to change the wetting properties of surfaces. The underlying mechanism is, however, not fully understood and additional experiments are needed. For that, we have replaced the DTAB surfactants used in the original work [1] by arylazopyrazole triethylammonium bromide (AAP-TB) which is a cationic surfactant that can change the surface tension at the air-water interface to a large extent through E/Z photoisomerization [2]. This offers to fine tune the contact angle during EDeW by E/Z photoisomerization of AAP-TB and we find a further increase in contact angle by $\sim 6^\circ$ when the samples were irradiated by UV light that triggers photoisomerization from the E to the less surface-active Z isomer. Li et al.[1] suggested that surfactants are deposited on the silicon oxide surface through the EDeW process. In order to study the possible deposition of surfactants and the role of a possible prewetting layer outside of the drop and at some distance from the 3-phase contact line we have done sum-frequency generation (SFG) spectroscopy and find that surfactants are deposited even several mm adjacent to the drop and that their structure as well as the structure of the accompanying water layer changes drastically close to the 3-phase contact line. [1] Li et al. Nature, 572, 507-510 (2019) [2] Schnurbus et al. J. Phys. Chem. B 124, 6913 (2020).

DY 52.5 Fri 10:45 H 0110

Light-Triggered Manipulations of Droplets All in One: Reversible Wetting, Transport, Splitting, and Merging — ●MAREN UMLANDT, NINO LOMADZE, and SVETLANA SANTER — University of Potsdam, Potsdam, Germany

We report on light-triggered droplet manipulation such as reversible wetting, splitting, merging, and transport [1]. The unique feature is that the changes in the wetting properties of anisotropic liquids adsorbed on photo-switchable films can be triggered by application of optical stimuli, which lead to changes in the morphology of the surfaces. The adaptive films consist of an azobenzene-containing surfactant attached to oppositely charged polymer chains. Under exposure to irradiation with light, the azobenzene photo-isomerizes between trans- and cis-states, resulting in changes in surface energy and orientation of surfactant tails in film [2]. The increase in the surface temperature due to absorption of light by the azobenzene groups [3] enables diverse processes of droplet manipulation. Using a moving light spot, we demonstrate the locomotion of the droplet over macroscopic distances. Our findings could lead to the application of a programmable workbench for manipulating and operating an ensemble of droplets.

We thank for funding DFG and RFBR.

[1] Umlandt, M. et al. ACS Applied Materials & Interfaces 2022 14 (36), 41412-41420 [2] Arya, P. et al. J. Chem. Phys. 2020, 152, 024904 [3] Zakharov, A. V. et al. Phys. Rev. E 2017, 96, 052705

15 min. break**Invited Talk**

DY 52.6 Fri 11:15 H 0110

Of Singularities and Controversies: The Soft Wetting Enigma — ●STEFAN KARPITSCHKA — University of Konstanz

The surface mechanics of soft solids are ubiquitously important in nature and technology. Static and dynamic wetting of soft polymer gels by simple liquids has emerged as an archetypical model system: The singular capillary traction at the edge of a droplet creates a micro-scale wetting ridge which slows down dramatically the macroscopic dynamics. Capillary, elastic, viscous and osmotic effects all contribute simultaneously in a highly non-linear regime, which has sparked controversial discussions of the underlying theoretical description. In this talk I will present recent measurements on ultra-thin to ultra-soft materials, along with new theoretical and numerical results, scrutinizing sources of non-linear behavior in both statics and dynamics.

DY 52.7 Fri 11:45 H 0110

Dynamics of Moving Droplets on Lubricated Polymer Brushes — ●RODRIQUE BADR¹, LUKAS HAUER^{2,3}, DORIS VOLLMER³, and FRIEDERIKE SCHMID¹ — ¹Johannes Gutenberg University, Mainz — ²Humboldt-Universität zu Berlin, Berlin — ³Max Planck Institute for Polymer Research, Mainz

The interaction of liquid droplets with lubricated substrates is rich with interesting physics combining thermodynamics, polymer science, and fluid dynamics, and has the potential for various industrial applications. In this work we focus on the dynamics of droplets moving on lubricated polymer brushes. In previous work, we showed the existence of a cloaking transition where the lubricant covers the surface of the droplet at equilibrium. Here, we investigate the influence of this cloak on the dynamics, in addition to its properties during the dynamical steady state. In addition, we investigate the characteristic of the wetting ridge, as well as the flow of the droplet, and quantify the friction forces felt by the droplet during its motion.

DY 52.8 Fri 12:00 H 0110

Modeling the growth of biofilms on soft substrates — ●ANTHONY PIETZ¹, KARIN JOHN², and THIELE UWE³ — ¹Institute for theoretical physics, University of Münster — ²Institute for theoretical physics, University of Münster — ³Research Associate at the CNRS Laboratoire Interdisciplinaire de Physique LIPhy Grenoble - France

We investigate the influence of substrate softness on biofilm growth amending the thin-film model developed by Trinschek et al for rigid solid substrates [1] by the inclusion of a simple description of an elastic substrate [2]. Wettability (described in the mesoscopic model by a wetting energy) is a key factor in the transition between arrested and continuous spreading on rigid substrates [1]. Our focus are changes in the spreading process with changing character of the substrate studied by time simulations of 2d drops/biofilms at fixed surface tension and initial drop volume. We find that with increasing softness from rigid via elastic to liquid-like substrate the spreading velocity of the biofilm decreases at fixed biofilm growth rate and wettability. Further, we discuss how these changes depend on wettability and growth rate. In particular, we show that the transition between arrested and continuous spreading is for increasing softness shifted towards larger wettability and larger growth rate.

[1] S. Trinschek, K. John, S. Lecuyer, and U. Thiele, *Phys. Rev. Lett.* 119, 078003 (2017).

[2] C. Henkel, J. H. Snoeijer, and U. Thiele, *Soft Matter* 17, 10359 (2021).

DY 52.9 Fri 12:15 H 0110

Chemically Active Wetting — ●SUSANNE LIESE¹, XUEPING ZHAO², CHRISTOPH WEBER¹, and FRANK JÜLICHER³ — ¹Faculty of Mathematics, Natural Sciences, and Materials Engineering: Institute of Physics, University of Augsburg, Augsburg, Germany — ²Department of Mathematical Sciences, University of Nottingham Ningbo China — ³Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Wetting of liquid droplets on passive surfaces is ubiquitous in our daily lives, and the governing physical laws are well-understood. When surfaces become active, however, the governing laws of wetting remain elusive. Here we derive the non-equilibrium thermodynamic theory for active wetting, where the surface is active due to a binding process that is maintained away from equilibrium. We show that active binding fundamentally changes the wetting behavior, leading to steady, non-equilibrium states with droplet shapes reminiscent of a pancake or a mushroom. The origin of such anomalous shapes can be explained by mapping to electrostatics, where pairs of binding sinks and sources correspond to electrostatic dipoles along the triple line. This is an example of a more general analogy, where localized chemical activity gives rise to a multipole field of the chemical potential. The underlying physics is relevant for cells, where droplet-forming proteins can bind to membranes accompanied by the turnover of biological fuels.

DY 52.10 Fri 12:30 H 0110

Intracellular wetting between biomembranes and liquid-like condensates — ●LUKAS HAUER¹, KATHARINA SPROBECK¹, AMIR HOUSHANG BAHRAMI^{2,3}, and ROLAND L. KNORR^{1,4} — ¹Humboldt Universität zu Berlin — ²Bilkent University, Ankara — ³MPI-DS, Göttingen — ⁴University of Tokyo

Wetting has been recently identified as physiologically important in fundamental cellular processes: phase-separated condensates (e.g., proteins and RNA) form liquid droplets in cells and interact with membranes, e.g., during autophagy in eukaryotic cells or protein storage in plant vacuoles. Upon contact, the droplets can exert wetting forces on the membrane that deforms. This creates a competition of mechanical forces of the membrane elasticity and the droplet capillarity, giving rise to elastocapillary phenomena. In this talk, I will present a minimal model system comprising giant lamellar vesicles (GUVs) filled with aqueous phase-separating polymers (PEG/Dextran). We create liquid-liquid interfaces inside GUVs by osmotic quenches, yielding deformed vesicles with excess membrane area. The excess membrane accumulates at the liquid-liquid interface and assumes differing morphologies, ranging from micro-tubules to sheets, to stomatocytes. We find that the morphology transition depends on the liquid-liquid surface tension. Our results will help to explain resembling in vivo observations during the morphogenesis of protein storage vacuoles in plants.