CPP 35: Focus Session: Wetting on Adaptive Substrates I (joint session CPP/DY/O)

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

Time: Thursday 9:30–11:00 Location: H 0107

Invited Talk CPP 35.1 Thu 9:30 H 0107

Extraordinarily slippery liquid-repellent surfaces using self-assembled monolayers — •Robin Ras — Aalto University, Espoo, Finland

Water-repellent surfaces have the attractive property of staying dry, and find applications in self-cleaning, anti-icing, anti-fogging and much more. Liquid-repellent surfaces, especially smooth solid surfaces with covalently grafted flexible brushes or alkyl monolayers, are the focus of an expanding research area.[1] Surface-tethered flexible species are highly mobile at room temperature, giving solid surfaces a unique liquid-like quality and unprecedented dynamical repellency.

We challenge two common assumptions on liquid-repellency.[2] It is generally assumed that water-repellent surfaces requires hydrophobicity. We demonstrate a hydrophilic surface with the unusual combination of low sliding angle and low contact angle. Surface heterogeneity is generally acknowledged as the major cause of increased contact angle hysteresis and friction of droplets. Here we challenge this long-standing premise for chemical heterogeneity at the molecular length scale.

Furthermore, we demonstrate world's most slippery surface, by combining self-assembled monolayers and surface structuring. Finally, by a suitable surface texture, we can trap a thin air layer for months, opening new strategies for underwater applications.[3]

[1] Nature Chemistry Reviews (2023) https://doi.org/10.1038/s41570-022-00455-w[2] Nature Chemistry (2023) https://doi.org/10.1038/s41557-023-01346-3 [3] Nature Materials (2023) https://doi.org/10.1038/s41563-023-01670-6

CPP 35.2 Thu 10:00 H 0107

Volatile binary mixtures on polymer brushes — •Jan Diekmann und Uwe Thiele — Institut für Theoretische Physik, Universität Münster, 48149 Münster, Germany

We present a mesoscopic thin-film model in gradient dynamics form for binary liquid mixtures on brush-covered substrates incorporating volatility in a narrow gap. Thereby, we expand models established in [1, 4-6] by incorporating two substances present in each of three bulk phases - liquid, brush and gas. We discuss the different contributions to the free energy, thereby employing Flory-Huggins theory of mixing for the condensed phases and assuming ideal gases for the vapor phase. Interface energies are modeled as linear interpolations of known limiting cases. The resulting six-field model is then analyzed with numerical time simulations showing results with a focus on lateral concentration gradients, notably at the contact line.

[1] S. Hartmann, C. Diddens, M. Jalaal, and U. Thiele. JFM 960, 2023. doi: 10.1017/jfm.2023.176. [2] S. Hartmann, J. Diekmann, D. Greve, and U. Thiele. 2023. doi: 10.48550/ARXIV.2311.07307. [3] S. Schubotz, Q. A. Besford, S. Nazari, P. Uhlmann, E. Bittrich, J.-U. Sommer, and G. K. Auernhammer. Langmuir, 39, 2023. doi: 10.1021/acs.langmuir.2c03009. [4] L. A. Smook, G. C. R. van Eck, and S. de Beer. Macromolecules, 53, 2020. doi: 10.1021/acs.macromol.0c02228. [5] U. Thiele and S. Hartmann. EPJ-ST 229, 2020. doi:10.1140/epjst/e2020-900231-2. [6] Özlem Kap, S. Hartmann, H. Hoek, S. de Beer, I. Siretanu, U. Thiele, and F. Mugele. JFM 158, 2023. doi: 10.1063/5.0146779.

CPP 35.3 Thu 10:15 H 0107

Wetting Phenomena in Hierarchically Porous Silicon: How Experiments and 2D Fluid-Dynamic Simulations Complement Each Other — •Stella Gries[1,2], Stefan Schulz[1], Marc Thelen[1,2], Silja Flenner[3], Imke Greving[3], and Patrick Huber[1,2] — [1]Institute for Materials and X-ray Physics, Hamburg University of Technology, Hamburg, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [3]Institute of Materials Physics, Helmholtz Zentrum Hereon, Geesthacht, Germany

Nature is an expert in designing highly efficient, multi-functional (hybride-)materials such as hierarchically capillary systems in respiratory systems or plants. These systems achieve large internal surfaces while allowing an optimized mass transport. This is used in plants to perform capillarity- induced motions, transport substances to reaction sites and remove educts from chemical processes. We are aiming to mimic such systems with artificially produced hierarchically porous silicon. The bimodal, hierarchical structure leads to a different imbibition behavior than porous systems with a monomodal pore-size distribution. Therefore, we used 2D finite element fluid dynamic simulations to achieve deeper insights into single-pore events and competing Laplace pressures in pore sections with distinct pore sizes. The simulations are related to the experimental results from dilatometry, mass-uptake and synchrotron-based, in-situ X-ray radiography imbibition experiments. This allows a complete description of the transport phenomena and will help us to tailor the material for applications in capillarity-driven pumps or energy harvesting from natural processes.

CPP 35.4 Thu 10:30 H 0107

Percolation in Networks of Liquid Diodes — Camilla Sammartino, Yair Shokef, and •Bat-El Pinchasik — Tel Aviv University, School of Mechanical Engineering, Israel

Liquid diodes are surface structures that facilitate the spontaneous flow of liquids in a specific direction. In nature, they are used to increase water collection and uptake, reproduction, and feeding. However, pump-free large networks with directional properties are exceptional and are typically limited up to a few centimeters. Here, we simulate, design, and 3D print networks consisting of hundreds of liquid diodes. We provide structural and wettability guidelines for directional transport of liquids through these networks and introduce percolation theory in order to identify the threshold between a connected network, which allows fluid to reach specific points, and a disconnected network. By constructing well-defined networks with uni- and bidirectional pathways, we experimentally demonstrate the applicability of models describing isotropically directed percolation. We accurately predict the network permeability and the liquid final state. These guidelines are highly promising for the development of structures for spontaneous, yet predictable, directional liquid transport. In addition, they comprise an initial realization of complex liquid circuits, analogoues to electric circuits.

CPP 35.5 Thu 10:45 H 0107

Wetting underneath droplets on an oily surface — •Shiva Moradimehr and Kirsten Harth — Fachbereich Technik, TH Brandenburg, Brandenburg a. d. Havel

When a liquid drop impacts on a smooth surface, a thin layer of air evolves between the drop and the surface. The drop deforms under the influence of the ambient air that needs to be squeezed out before the drop can touch the substrate. The actual air layer profile depends on the impact velocity, ambient gas, drop liquid as well as the deformability of the substrate. For small impact Weber number, the air film ruptures before drop rebound. The wetting front connecting the drop and layer liquids propagates at velocities of few meters per second.

We study the wetting front velocity for droplets impacting on hard substrates covered by thin oil layers using high-speed interferometry at oblique incidence. The impact velocity, viz. the thickness of the entrained air layer, and the oil layer properties are varied. Both a model for contact spreading on a thin film or an film-rupture based model are initial candidates to describe the wetting front propagation.