CPP 34: Wetting, Droplets and Microfluidics I (joint session DY/CPP)

Time: Wednesday 10:00–13:00 Location: ZEU 147

CPP 34.1 Wed 10:00 ZEU 147

Crises and chaotic scattering in hydrodynamic pilot-wave experiments — George Choueiri[1,2], Balachandra Suri[1,3], Jack Merrin[1], Maksym Serbyn[1], Björn Hof[1], and •Nazmi Burak Budanur[1,4] — [1]Institute of Science and Technology Austria, 3400 Klosterneuburg, Austria — [2]MIME Department, University of Toledo, Toledo, Ohio 43606, USA — [3]Department of Mechanical Engineering, Indian Institute of Science, Bengaluru 560012, India — [4]Max Planck Institute for the Physics of Complex Systems, 01187 Dresden, Germany

Theoretical foundations of chaos have been predominantly laid out for finite-dimensional dynamical systems, such as the three-body problem in classical mechanics and the Lorenz model in dissipative systems. In contrast, many real-world chaotic phenomena, e.g., weather, arise in systems with many (formally infinite) degrees of freedom, which limits direct quantitative analysis of such systems using chaos theory. In the present work, we demonstrate that the hydrodynamic pilot-wave systems offer a bridge between low- and high-dimensional chaotic phenomena by allowing for a systematic study of how the former connects to the latter. Specifically, we present experimental results, which show the formation of low-dimensional chaotic attractors upon destabilization of regular dynamics and a final transition to high-dimensional chaos via the merging of distinct chaotic regions through a crisis bifurcation. Moreover, we show that the post-crisis dynamics of the system can be rationalized as consecutive scatterings from the nonattracting chaotic sets with lifetimes following exponential distributions.

CPP 34.2 Wed 10:15 ZEU 147

Chemically Active Wetting — •Susanne Liese[1], Xueping Zhao[2], Frank Jülicher[3], and Christoph Weber[1] — [1]Universität Augsburg, Augsburg, Germany — [2]Xiamen University, Xiamen, China — [3]MPI/PKS, Dresden, Germany

In living cells, wetting of condensed phases on membrane surfaces provides a mechanism for positioning biomolecules. Biomolecules are also able to bind to such membrane surfaces. In living cells, this binding is often chemically active as it is kept out of equilibrium by the supply of energy and matter. Here, we investigate how active binding on membranes affects the wetting of condensates. To this end, we derive the non-equilibrium thermodynamic theory of active wetting. We find that active binding significantly alters the wetting behavior leading to non-equilibrium steady states with condensate shapes reminiscent of a fried egg or a mushroom. We further show that such condensate shapes are determined by the strength of active binding in the dense and dilute phases, respectively. Strikingly, such condensate shapes can be explained by an electrostatic analogy where binding sinks and sources correspond to electrostatic dipoles along the triple line. Through this analogy, we can understand how fluxes at the triple line control the three-dimensional shape of condensates.

CPP 34.3 Wed 10:30 ZEU 147

Stimuli-responsive high aspect ratio surfaces for wetting studies — •Gissela Constante[1], Indra Apsite[1], Paul Auerbach[2], Sebastian Aland[2], Dennis Schönfeld[3], Thorsten Pretsch[3], Pavel Milkin[1], and Leonid Ionov[1,4] — [1]Uni Bayreuth, Bayreuth, Germany — [2]HTW Dresden, Dresden, Germany — [3]Fraunhofer IAP, Postdam, Germany — [4]Bavarian Polymer Institute, Bayreuth, Germany

The fabrication of switchable surfaces has been of interest in different fields such as biotechnology, industry, robotics, and others. The fabrication of these shape-changing bioinspired surfaces is a challenge due to the limited availability of materials and methods. In this research, an exceptional high aspect ratio lamellar surface topography was fabricated by melt-electrowriting of microfibers of a shape-memory thermo-responsive polyurethane. Two different types of stimuli: temperature and light exposition were applied to modify the mechanical properties and by it the deformation and recovery of the original surface. Wetting studies showed that the deformation of the high aspect ratio lamellar surface can be tunned not only manually, but as well by a liquid droplet. This behavior is controlled by variation of temperature conducted by direct heating/cooling or by exposure to light when the lamellae were stained with black ink. The liquid in combination with thermo-responsive topography presents a new type of wetting behavior. This feature opens the possibility to apply such topographies for the design of smart elements for microfluidic devices, for example, smart valves.

CPP 34.4 Wed 10:45 ZEU 147

A Study about Shock-Induced Spallation in Mono- and Nanocrystalline High-Entropy Alloys — •Daniel Thürmer[1], Nina Merkert née Gunkelmann[1], Shiteng Zhao[2], Orlando Deluigi[3], Camelia Stan[4], Iyad Alhafez[5], Herbert Urbassek[5], Marc Meyers[6], and Eduardo Bringa[3,7] — [1]Institute of Applied Mechanics, Clausthal University of Applied Technology, Arnold-Sommerfeld-Stra*e, D-38678 Clausthal-Zellerfeld, Germany — [2]School of Material Science and Engineering, Beihang University, 37 Xueyuan Rd, Haidian District, Beijing, China, 100191 — [3]CONICET and Faculty of Engineering, University of Mendoza, Mendoza, 5500, Argentina — [4]Advanced Light Source Facility, Lawrence Berkeley National Laboratory, One Cyclotron Road, Berkeley, CA 94720, United States — [5]Physics Department and Research Center OPTIMAS, University Kaiserslautern, Erwin-Schr*odinger-Stra*e, D-67663 Kaiserslautern, Germany — [6]Mechanical and Aerospace Department, Univ. of California San Diego, La Jolla, CA 92093, United States — [7]Centro de Nanotecnología Aplicada, Universidad Mayor, Santiago, Chile

High-entropy alloys are highly attractive for future applications in the technical field thanks to their incredible potential regarding mechanical properties. Although they are increasingly sparking interest for future usage, their general understanding is not yet complete. To further understand high-entropy alloys and their capabilites, we studied the influence of shock-induced spallation on mono- and nanocrystalline high-entropy alloys with varying grain sizes.

CPP 34.5 Wed 11:00 ZEU 147

Instability of Active Fluid Interfaces in Microfluidics — •Kuntal Patel and Holger Stark — Institut für Theoretische Physik, Technische Universität Berlin, Berlin, Germany

In recent years, microfluidic lab-on-a-chip devices have emerged as efficient miniaturized flow control platforms. Specifically, the advent of nonlinear microfluidics has opened a new avenue for chemical and biomedical applications such as droplet formation and cell sorting. In this work, we integrate ideas from active matter into a microfluidic setting and try to understand the mechanism and practical relevance of resulting microfluidic flows.

The present setup consists of two vertically stacked fluid layers with identical densities but different viscosities, sandwiched between the walls of a microfluidic channel. The interface separating both fluids is initialized with uniformly distributed active particles, which induce force dipoles that generate flows in the adjacent fluids.

Our hybrid lattice-Boltzmann finite-difference simulations reveal that when we perturb the fluid interface covered with extensile force dipoles $\updownarrow$, it eventually returns to its flat state irrespective of the strength of interfacial tension. In contrast, contractile force dipoles $\downarrow\uparrow$ lead to activity-driven interfacial instability. However, such instability emerges only above a critical value of the activity, which is proportional to the interfacial tension. We further examine the mechanism of instability and quantify the effect of viscosity contrast and perturbation wavelength. Lastly, we demonstrate the systematic formation of droplets using the present interfacial instability.

CPP 34.6 Wed 11:15 ZEU 147

Optically controlled micro-transport with reduced heating impact — •Antonio Minopoli, Elena Erben, Susan Wagner, and Moritz Kreysing — Max Planck Institute of Molecular Cell Biology and Genetics, Dresden, Germany

Recently it was demonstrated that thermoviscous flows can be used to move the cytoplasm of cells and developing embryos. These laser-induced intracellular flows (aka FLUCS), reach velocities comparable with those occurring during early stages of embryogenesis. As a side effect, the laser scanning may also cause temperature gradients across the sample (1-3 Kelvins) that could give rise to out-of-equilibrium phenomena. Here, we demonstrate that exploiting symmetry relations during the laser scan, we disentangle heating and flows. Specifically, since the flow speeds depend on the repetition frequency rather than on the beam velocity, it is possible to accelerate the scanning of the

primary scan pattern, effectively compressing the scan signal to occupy only a fraction of the original period, and allowing to complement the flow stimuli by flow-invariant heat stimuli. We introduce strategies to complement even complex primary scan patterns by secondary heating stimuli thereby yielding a near isothermal temperature distribution and still generating significant net flows. As we experimentally show, the resulting temperature distributions are near homogenous across the sample (standard deviations 5-10 times lower than those measured with standard FLUCS) and can therefore be better compensated for by ambient cooling. In the next future, ISO-FLUCS may become the new standard for optofluidic manipulations within biological systems.

15 min. break

CPP 34.7 Wed 11:45 ZEU 147

3D passive non-mechanical microfluidic valves fabricated using grayscale lithography — •Sebastian Bohm[1,3], Hai Binh Phi[2,3], Erich Runge[1], Lars Dittrich[3], and Steffen Strehle[2] — [1]TU Ilmenau, FG Theoretische Physik I — [2]TU Ilmenau, FG Mikrosystemtechnik — [3]5microns GmbH, 98693 Ilmenau

Passive non-mechanical valves represent a promising method for rectifying flows in micro- or nanofluidic systems [1]. They are very robust due to the absence of mechanical parts, easy to fabricate, and allow the implementation of efficient microfluidic systems such as micropumps [2,3]. However, with existing methods, the fabrication of fully three dimensional (3D) structured geometries is very hard to achieve. Here, a new and easy to implement method for the fabrication of three-dimensional valves is presented: Grayscale lithography followed by a proportional transfer with reactive ion etching is utilized to create 3D diffuser valves in silicon and glass substrates. We show that higher diodicities were achieved with 3D diffuser valves compared to conventional diffuser valves. These experimental findings correspond fit very well to the predictions of our numerical simulations. In combination with highly efficient optimization methods for two-dimensional Tesla valves, the fabrication of even more efficient 3D Tesla valves is hence now within reach.

[1] Bohm, S. et al.; npg Microsystems & Nanoengineering (8), 97 (2022)
[2] Bohm, S. et al.; COMSOL Conference 2020 Europe, 14-15. Oct. 2020 online
[3] Hoffmann, M. et al.; German patent DE112011104467 (2017)

CPP 34.8 Wed 12:00 ZEU 147

Coalescence of nematic droplets in quasi 2D liquid crystal films — •Christoph Klopp and Ralf Stannarius — Otto von Guericke University, Institute of Physics

Coalescence of droplets is ubiquitous in nature and modern technology. Various experimental and theoretical studies explored droplet dynamics in three dimensions (3D) and on two-dimensional (2D) solid or liquid substrates, e.g. [1-4]. Here, we demonstrate coalescence experiments of isotropic and nematic droplets in quasi-2D liquids, viz. overheated smectic A freely suspended films. We investigated their dynamics experimentally and measured the shape deformation during the entire merging process using high-speed imaging and interferometry. This system is a unique example where the lubrication approximation can be directly applied, and the smectic membrane plays the role of a precursor film. Our studies reveal the scaling laws of the coalescence time depending on the droplet size and the material parameters. We also compared the dynamics of isotropic and nematic droplets and additionally analyzed the results based on an existing model for liquid lens coalescence on liquid and solid surfaces [4].

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References:

[1] J. D. Paulsen et al., Nat. Commun., 5, 3182 (2014) [2] D. G. A. L. Aarts et al., Phys. Rev. Lett., 95, 164503 (2005). [3] M. A. Hack et al., Phys. Rev. Lett. 124, 194502 [4] N. S. Shuravin et al., Phys. Rev. E, 99, 062702 (2019) [5] C. Klopp et al., Langmuir, 36, 10615 (2020)

CPP 34.9 Wed 12:15 ZEU 147

effect of deposition method on the static contact angle of nanodroplets measured by AFM — •mohammadali hormozi and regine von klitzing — soft matter at interface, tu darmstadt, darmstadt, Germany

The wetting properties of substrates are often described by the static contact angle of a particular liquid. The contact angle depends on many parameters like substrate chemistry, liquid properties, and environment condition. In this study, we show that the method of depositing the liquid phase on the solid phase can play an important role for the static contact angle. For this purpose, microscale droplets of non-volatile liquids including Polyethylene Glycol (PEG200) and Squalane are deposited on the silanized substrate using four different methods. These methods are either based on nucleation (condensation and solvent exchange) or printing (inkjet and microcontact printing) of droplets. The contact angle of the microdroplets is scanned with an AFM and allows detailed analysis of the three phase contact line on a nm scale. The final static contact angle of the microdroplets is compared with the macroscopic contact angle determined by optical methods. Droplets formed via nucleation show smaller contact angle than printed ones. The latter ones were closer to the macroscopic contact angle. We will discuss this phenomenon.

CPP 34.10 Wed 12:30 ZEU 147

Fingering contact propagation between a droplet and a thin liquid film — •Kirsten Harth — Fachbereich Technik, TH Brandenburg — MRTM und MARS, Otto von Guericke Universität Magdeburg

When impacting droplets approach a hard plane substrate slowly, so that the Weber number is below approximately 5, a contact-less rebound will occur due to the entrainment of ambient gas. On slightly deformable and smooth spin-coated liquid films upon a rigid solid, this effect is more robust and may occur until slightly higher Weber numbers. Deformation of the thin film is usually ignored while it is proven to be present. The deformation amplitude depends on the impact dynamics as well as the thickness and viscosity of the surficial oil layer. At slightly higher impact velocities, i.e. slightly higher Weber numbers, delayed contact formation between the film liquid and the droplet occurs. Depending on the layer properties, interestingly, the contact line may be unstable displaying a fingering texture. Instability occurs independently of whether the drop and film liquid differ or not. We present and analyze this phenomenon.

CPP 34.11 Wed 12:45 ZEU 147

Universality in One-Dimensional Breath Figures — •Daniel Dernbach, Adrian Häussler-Möhring, M Muhammad, and Jürgen Vollmer — Institut für Theoretische Physik, Universität Leipzig, Brüderstr. 16, D-04103 Leipzig, Germany

Patterns of droplets which condense upon substrates reveal self-similar features. They are described by a scaling theory with a non-trivial exponent that has been related to the fractal dimension of the scaling of the free area ("porosity") in between droplets. There is no agreement if this exponent is universal or affected by the dynamics. Here, we present numerical data that address the dependence of the asymptotic scaling of the porosity for hyper-spherical droplets growing on one-dimensional substrates. We vary the droplet dimension and interactions. For a given dimension the exponent is universal up to a critical range of interaction. For longer-ranged interactions the scaling depends on the dynamics.