

## CPP 87: Wetting and Liquids at Interfaces and Surfaces I (joint session CPP/O/DY)

Time: Thursday 9:30–13:00

Location: ZEU 255

CPP 87.1 Thu 9:30 ZEU 255

**Designing Pickering Emulsions for Catalysis: Influence of Nanoscale Particle Properties on Microscale Droplets** — ●SEBASTIAN STOCK<sup>1</sup>, ANNIKA SCHLANDER<sup>1</sup>, KAI SPANHEIMER<sup>1</sup>, MARESA KEMPIN<sup>2</sup>, DMITRIJ STEHL<sup>1</sup>, ANJA DREWS<sup>2</sup>, MARKUS GALLEI<sup>3</sup>, and REGINE VON KLITZING<sup>1</sup> — <sup>1</sup>TU Darmstadt, Darmstadt, Germany — <sup>2</sup>HTW Berlin, Berlin, Germany — <sup>3</sup>Universität des Saarlandes, Saarbrücken, Germany

Pickering Emulsions (PEs) describe emulsions stabilized by surface-active particles. The aim of the present work is to design PEs as a reaction environment for catalytic reactions. As a model reaction the hydroformylation of 1-dodecene is investigated. Due to the PEs high stability separation methods with outstanding energy efficiency are applicable e. g. the separation of the oil phase by nanofiltration. Many microscopic and macroscopic PE properties are dominated by the nanoscale properties of the particles. In order to distinguish the impact of particle surface charge both positively and negatively charged silica spheres were prepared. This was achieved by adequate surface modification. The resulting nanoscale particle properties concerning size, shape, charge, and hydrophobicity were investigated via Transmission Electron Microscopy (TEM),  $\zeta$ -potential and sessile drop measurements, the effect on the microscopic emulsion properties were studied with microscopy and the PEs reaction behavior including yield and stability was evaluated.

CPP 87.2 Thu 9:45 ZEU 255

**A Thermodynamic Consistent, Instantaneous Dividing Surface to Study Wetting Phenomena** — ●AMAL KANTA GIRI and MARCELLO SEGA — Helmholtz Institute Erlangen-Nürnberg for Renewable Energy, Forschungszentrum Jülich, Fürther Straße 248, 90429 Nürnberg, Germany

A detailed knowledge of the microscopic structure and dynamics in the interfacial region of soft materials is a necessary step on the way to develop novel materials and is also key to a deeper understanding of the statistical mechanics of fluid interfaces out of equilibrium. The presence of thermal capillary waves, however, hinders efforts to investigate the local structure of interfaces by smearing out observable quantities computed in the global reference frame. To recover a detailed picture of the interface neighborhood, one needs to compute observables in the local, instantaneous reference frame located at the interface, although the determination of this frame is, in general, not unique.

Here, we report on the possibility of using computational geometry approaches to determine the set of instantaneous surface atoms in a way which is thermodynamically consistent with the Gibbs (equimolar) dividing surface. We apply these methods to the determination of the instantaneous, fluctuating contact line of droplets on solid substrates, with an outlook on the problem of dynamic wetting of soft, deformable substrates.

CPP 87.3 Thu 10:00 ZEU 255

**Concentration measurements in binary liquids via Raman spectroscopy** — ●ALENA K. BELL and ROBERT W. STARK — Physics of Surfaces, Materialwissenschaften, TU Darmstadt, Alarich-Weiss-Str. 16, 64287 Darmstadt, Deutschland

The optical measurement of concentration gradients in liquid mixtures plays a crucial role in understanding transport processes in various technical applications such as printing or medical technology. In particular Raman spectroscopy offers a direct approach to identify the substances and to quantify the concentration of the components in a binary liquid. In order to quantify concentration gradients confocal Raman spectroscopy can provide the necessary spatial and temporal resolution that is needed to monitor transport processes as they occur during the evaporation of binary droplets or during mixing processes in microchannels. To this end, chemically similar substances such as alcohols of different molecular weight need to be differentiated either through the analysis of the fingerprint region or through chemical labelling. However, using the weak Raman signals in fingerprint region reduces the temporal resolution drastically which makes chemical labelling much more convenient. We discuss the advantages and disadvantages of chemical labelling in order to discriminate spectroscopically between the components of a binary liquid. By using this approach concentration gradients can be calculated by comparing relative peak

intensities and correlating these results with calibration curves. Thus, the temporal and spatial evolution of concentration gradients in binary mixtures of chemically similar fluids can be analysed.

CPP 87.4 Thu 10:15 ZEU 255

**Hard sphere electrolyte solutions at heterogeneously charged substrates** — ●MAXIMILIAN MUSSOTTER<sup>1</sup>, MARKUS BIER<sup>2</sup>, and S. DIETRICH<sup>1</sup> — <sup>1</sup>Max-Planck Institut für Intelligente Systeme und Universität Stuttgart, 70569 Stuttgart, Germany — <sup>2</sup>University of Applied Sciences Würzburg-Schweinfurt, 97421 Schweinfurt, Germany

The structure of a dilute electrolyte solution close to a surface carrying a non-homogeneous surface charge distribution is investigated by means of classical density functional theory (DFT) within the approach of fundamental measure theory (FMT). In the case of electrolyte solutions, the effects of these inhomogeneities are particularly severe due to the corresponding length scale being the Debye length, which is large compared to molecular sizes. A fully three-dimensional investigation is performed, which accounts explicitly for the solvent particles, and thus provides insight in effects of ion-solvent coupling. The present work introduces a powerful framework to study a broad range of possible surface charge heterogeneities even beyond the linear response regime, showing a sensitive dependence of the density profiles of the fluid components and of the electrostatic potential on the magnitude of the charge as well as on the short ranged details of the surface charge pattern.

CPP 87.5 Thu 10:30 ZEU 255

**Core-shell latex colloids as interfaces for tailoring wetting properties** — CALVIN J. BRETT<sup>1,2,3</sup>, JOAKIM ENGSTRÖM<sup>3,4</sup>, VOLKER KÖRSTGENS<sup>5</sup>, PETER MÜLLER-BUSCHBAUM<sup>5,6</sup>, EVA MALMSTRÖM<sup>4</sup>, and ●STEPHAN V. ROTH<sup>1,4</sup> — <sup>1</sup>DESY, 22603 Hamburg, Germany — <sup>2</sup>KTH, Dept. Mechanics, SE-10044 Stockholm, Sweden — <sup>3</sup>WWSC, SE-10044 Stockholm, Sweden — <sup>4</sup>KTH, Dept. Fibre and Polymer Technology, SE-10044 Stockholm, Sweden — <sup>5</sup>TUM, Physik Department, 85748 Garching, Germany — <sup>6</sup>MLZ, TUM, 85748 Garching, Germany

Facile surface functionalisation of latex colloids makes them most promising materials for broad thin film applications. However, the effect of these colloids on chemical film and wetting properties is not easily evaluated. Core-shell particles can deform and coalesce on the nanoscale during thermal annealing yielding tailored physical properties. We investigated two different core-shell systems (soft and rigid) with identical shell but with chemically different core polymer and core size. These core-shell colloids are probed during thermal annealing on surfaces in order to investigate their behavior as a function of nanostructure size and rigidity. X-ray scattering allows us to follow the re-arrangement of the colloids and the structural evolution in situ during annealing. Evaluation by real-space imaging techniques reveals a disappearance of the structural integrity and a loss of colloids' boundaries. We present the possibility to tailor and fine-tune the wettability by tuning the core-shell colloid morphology in thin films, thus providing a facile template methodology for repellent surfaces.

CPP 87.6 Thu 10:45 ZEU 255

**Depleting Hydrogels with Oil Flows** — ●PHILIPP BAUMLI<sup>1</sup>, EMANUELA LORUSSO<sup>2</sup>, LUKAS HAUER<sup>1</sup>, AZADEH SHARIFI-AGHILI<sup>1</sup>, KATHARINA HEGNER<sup>1</sup>, MARIA D'ACUNZI<sup>1</sup>, BURKHARD DUENWEG<sup>1</sup>, JOCHEN GUTMANN<sup>2</sup>, HANS-JÜRGEN BUTT<sup>1</sup>, and DORIS VOLLMER<sup>1</sup> — <sup>1</sup>Max Planck Institute for Polymer Research, Ackermannweg 10, 55128 Mainz, Germany — <sup>2</sup>Deutsches Textilforschungszentrum Nord-West ÖP GmbH, Adlerstraße 1, 47798 Krefeld, Germany.

Hydrogels are ubiquitous in our daily lives. Applications range from jelly pudding and diapers to scaffolds in tissue engineering. A hydrogel-coating is covalently attached to a micropillar array. Swelling the hydrogel-coating with water establishes a liquid-infused surface (LIS). On LIS, liquid-depletion is synonymous with loss of functionality.

We demonstrate that the hydrogel-based LIS can be kept lubricated upon a shear-flow of oil for a wide variety of flow conditions independent of the exact nature of the hydrogel-coating. Dehydration of the hydrogel-coating is followed by confocal laser scanning microscopy and progresses linearly independent of flow conditions and hydrogel. The mechanism is explained with the help of an extended diffusion model.

CPP 87.7 Thu 11:00 ZEU 255

**Tracking nematic flows at microscales using small angle X-ray scattering** — ●PAUL STEFFEN<sup>1</sup>, ERIC STELLAMANN<sup>2</sup>, MICHAEL SPRUNG<sup>2</sup>, FABIAN WESTERMEIER<sup>2</sup>, and ANUPAM SENGUPTA<sup>3</sup> — <sup>1</sup>Göttingen — <sup>2</sup>Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, 22607 Hamburg, Germany — <sup>3</sup>Physics of Living Matter, Dept. of Physics and Materials Science, University of Luxembourg, Luxembourg

Liquid crystal microflows play a fundamental role in materials, modern display technologies, and biological systems. However, a quantitative, dynamic and spatially resolved measurement of the director field and surface anchoring remain a significant challenge. Here we present small angle X-ray measurements on stationary flows of 4-Cyano-4-pentylbiphenyl (5CB) in circular Kapton capillaries (under homeotropic and random planar anchoring) at temperatures between 280 and 310 K, and Ericksen numbers ranging from 0 to 200, with a spatial resolution of 1/1000 of the capillary dimension. The angular dependence of the scattering peaks from both periodic length scales was approximated by a double Gaussian fit with four parameters: amplitude, angle, width and background amplitude. The peak angles were found to be in good agreement with the director fields calculated using the Leslie-Ericksen theory. The width and the amplitude of the scattering patterns obtained from the larger length scale are less affected by the temperature than those from the smaller length scale.

15 min. break

CPP 87.8 Thu 11:30 ZEU 255

**Macroscopic Capillary Number for Characterization of Two-phase Flow in Porous Media** — ●HU GUO and RUDOLF HILFER — Institute for Computational Physics, Universität Stuttgart, Stuttgart, Germany

The Capillary number ( $Ca$ ) defined as the ratio of viscous force to capillary force is widely used to qualitatively characterize multiphase flow in porous media as in carbon dioxide geologic sequestration and chemical enhanced oil recovery (EOR). The main difficulty is to characterize forces properly. There exists 22 definitions for  $Ca$  (Guo et al, IOR 2020). The most concise definition is  $Ca = \frac{v\mu}{\sigma}$  with velocity  $v$ , viscosity  $\mu$  and interfacial tension  $\sigma$  (Saffman and Taylor, 1958). It is supported by core flooding tests and most widely used. However, this definition is less sound than the one that involves the wettability parameter (Moore and Slobod, 1955). Meanwhile, the values of these  $Ca$  are regarded as too small to reflect the actual force balance (Dullien, 1979). It was shown theoretically, that this  $Ca$  is microscopic in nature and incorrectly used (Hilfer and Øren, 1996, Trans. Porous Media).

We study the new macroscopic capillary number  $Ca = \frac{\mu\phi vL}{K P_b}$  with viscosity  $\mu$ , porosity  $\phi$ , velocity  $v$ , permeability  $K$ , length  $L$  and capillary breakthrough pressure  $P_b$  (Hilfer et al, 2015, Physical Review E). The new  $Ca$  explains some of the latest observations (Doorwar and Mohanty, 2017, SPE J; Qi et al, 2017, SPE J; Rabbani et al, 2018, PNAS; Zhao et al, 2019, PNAS) that contradict predictions obtained from the microscopic  $Ca$ . EOR field practice also verified that the macroscopic  $Ca$  is more profound.

CPP 87.9 Thu 11:45 ZEU 255

**Drop Impact on Hot Plates: Contact, Lift-Off and the Formation of Holes** — ●KIRSTEN HARTH<sup>1,2</sup>, SANG.HYEON LEE<sup>3</sup>, MAAIKE RUMP<sup>2</sup>, MINWOO KIM<sup>3</sup>, DETLEF LOHSE<sup>2</sup>, KAMEL FEZZAA<sup>4</sup>, and JUNG HO JE<sup>3</sup> — <sup>1</sup>Institute of Physics, Otto von Guericke University Magdeburg — <sup>2</sup>Physics of Fluid and Max Planck Center, University of Twente, The Netherlands — <sup>3</sup>X-Ray Imaging Center, Pohang University of Science and Technology, Korea — <sup>4</sup>X-Ray Science Division, Argonne Ntl. Laboratory, USA

Everyone who poured water into a hot pan has experienced the manifold boiling behaviours of drops impacting on a hot plate, a problem which is of high relevance in many technical applications. When the drop is gently deposited, and the surface temperature is sufficiently high, it hovers on a vapour layer (Leidenfrost effect). For impacting drops, this critical temperature for a contact-less rebound is substantially increased, and much harder to determine. In fact, determining contact times between drops and smooth substrates from side view imaging is impossible for most temperatures above the boiling point.

We combine High-Speed Total Internal Reflection and synchrotron X-Ray measurements to reliably determine contact times and the Leidenfrost temperature for drops impacting on smooth hot surfaces. Furthermore, we study the lift-off characteristics. A local minimum in

lift-off times correlates with spontaneous lamella rupture and the morphology of the contact.

CPP 87.10 Thu 12:00 ZEU 255

**Lucas-Washburn equation applies for four phase contact point** — ●PEYMAN ROSTAMI<sup>1,2</sup> and GÜNTER AUERNHAMMER<sup>1,2</sup> — <sup>1</sup>Max Planck Institute for Polymer Research, 55128, Mainz, Germany — <sup>2</sup>Leibniz Institute of Polymer Research, 01069, Dresden, Germany

A four-phase contact point, e.g., in merging of immiscible drops, is the point where the liquid-liquid interface advances along the contact line of one drop. The dynamics of drop merging involve various driving and dissipating forces in the dynamics of the four-phase contact point. The viscous friction, i.e. the flow field, within liquids is influenced by the different boundary conditions on the different interfaces (liquid-gas, liquid-liquid, liquid-solid). Additionally, Marangoni stresses between the two liquids and the spreading coefficients along the contact lines play a role. Effectively, these effects lead to a capillary force acting on the four-phase contact point. In total, the situation resembles the capillary flow in open V-shaped groove. The important difference is that, in the classical problem, the grooves are made out of two solid walls, but in the present case one of the \*walls\* is liquid, i.e., flowable and deformable. We investigate a range of liquids with different combination of physical properties (viscosity ratio, surface and interfacial tensions). The results show a good qualitative agreement for different liquids of the experimental results with the classical Washburn equation ( $h \sim \sqrt{\text{time}}$ ), where  $h$  is the filled length of the \*groove\*.

CPP 87.11 Thu 12:15 ZEU 255

**Simulations of Thermal Fluctuations with a Thin Film Lattice Boltzmann Model** — ●STEFAN ZITZ<sup>1</sup>, JENS HARTING<sup>1,2</sup>, and ANDREA SCAGLIARINI<sup>3</sup> — <sup>1</sup>Helmholtz Institute Erlangen-Nürnberg for Renewable Energy (IEK-11), Nuremberg, Germany — <sup>2</sup>Eindhoven University of Technology, Eindhoven, The Netherlands — <sup>3</sup>Consiglio Nazionale delle Ricerche, Rome, Italy

The effect of thermal fluctuations on thin film flows is an interesting yet challenging phenomenon. Although in experiments their presence is undeniable thermal fluctuations are often neglected in the analysis of the results. Also in simulations their inclusion is far from being trivial due to the stochastic nature of the fluctuations.

Here we present a numerical approach to include the influence of thermal fluctuations. Based on our newly developed lattice Boltzmann method we show how to effectively match the thin film regime and further how to include thermal fluctuations in a self consistent matter [1].

One problem of deterministic thin film simulations is the discrepancy between experimental and simulated rupture times in dewetting experiments. It has been shown that the experimental rupture times are shorter than the ones predicted by deterministic simulations. We will show that adding fluctuations does reduce the rupture time to better match the experimental results. To this end we will also address the importance of the fluid substrate interaction, e.g. the equilibrium contact angle  $\theta_{eq}$ .

S. Zitz, J. Harting et al., Phys. Rev. E 100:3, 033313, 2019

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**Impact of submillimetre-sized droplets on freely suspended liquid membranes** — ●FLORIAN VON RÜLING, ALEXEY EREMIN, and RALF STANNARIUS — Otto von Guericke University Magdeburg, Germany

Droplet impact and splashing phenomena at solid and fluid interfaces remain an exciting research topic with vast application possibilities [1]. Impact scenarios are primarily governed by capillary forces, inertia, oscillation dynamics of the droplets, and the dynamics of the thin air cushion entrapped between droplet and surface during impact [2,3]. We experimentally investigated the impact of large submillimetre- to millimetre-sized droplets on freely suspended smectic films. We were able to vary the droplet diameter from several hundred microns to one millimetre. Droplets can either be trapped or reflected by the film or tunnel through it, depending on geometrical and dynamical parameters. The film remains intact in all these scenarios. In addition to the drop size and impact velocity, material properties and the film thickness can affect the behaviour of both droplet and film.

[1] A. M. Worthington, The Splash of a Drop; Romance of Science. Society for the Promotion of Christian Knowledge, London, 1895.

[2] C. Antonini, A. Amirfazli, M. Marengo, Drop impact and wettability: From hydrophilic to superhydrophobic surfaces, Phys. Fluids

24 102104 (2012).

[3] S. Dölle, R. Stannarius, Microdroplets impinging on freely suspended smectic films: three impact regimes, *Langmuir* 31 6479 (2015).

CPP 87.13 Thu 12:45 ZEU 255

**Imbibition-Induced Deformation Dynamics in Nanoporous Media** — •JUAN SANCHEZ<sup>1</sup>, ZHUOQING LI<sup>2</sup>, MICHAEL FROEBA<sup>3</sup>, and PATRICK HUBER<sup>4</sup> — <sup>1</sup>Institute of Materials Physics, Hamburg University of Technology — <sup>2</sup>Institute of Materials Physics, Hamburg University of Technology — <sup>3</sup>Institute of Anorganic and Applied Chemistry, Hamburg University — <sup>4</sup>Institute of Materials Physics, Hamburg Uni-

versity of Technology

We present time-dependent macroscopic dilatometry experiments on the deformation of nanoporous monoliths (carbon and silica) upon spontaneous, capillarity-driven invasion of water. We find two distinct dynamical regimes. One of them can be quantitatively traced to deformations originating in changes in the surface stress at the inner pore walls (dynamic Bangham's regime) upon water invasion, whereas the second one results from Laplace pressure effects. Our study demonstrates that it is possible to dynamically monitor imbibition dynamics by simple dilatometry measurements.