CPP 24 POSTER Microfluidics

Time: Thursday 17:00–19:00 Room: P2

CPP 24.1 Thu 17:00 P2

Semiflexible polymer brushes in shear flow — •Lukas Holzer and Walter Zimmermann — Theoretische Physik Ia, Universität Bayreuth, D-95440 Bayreuth

We investigate semiflexible polymers with a persistence length of the order of the polymer length such as for actin-filaments. Anchored at a flat surface they are exposed to a linear shear flow. Results concerning their stationary and dynamical deformation with respect to their mean distance or with respect to the shear rate etc. are presented.

CPP 24.2 Thu 17:00 P2

Free-Surface shapes of strongly deformed driven micro-droplets — •Michael Schindler[1], Peter Talkner[1], Peter Hänggi[1], and Uwe Thiele[2] — [1]Institut für Physik, Universität Augsburg — [2]MPI Physik Komplexer Systeme, Dresden

We propose a Finite-Element algorithm to compute free surface shapes that are significantly deformed by an applied static (gravitation) or dynamic (surface-accoustic waves) driving. In the micro-fluidic regime, where the surface tension forces become important the central difficulty resides in the approximation of the discretized curvature. We present a method how the discretization of the free surface can automatically be kept regular using a smooth transition to the behaviour of a rubber band.

By employing a variational approach we can show that the surface position must be discretized with the same order of accuracy as the velocity components. Otherwise, the free-surface boundary problem will be inconsistently formulated and give rise to approximation errors, as numerical observations confirm.

As examples we show pending pinned droplets on a flat substrate under the sole influence of gravity and capillarity and also droplets driven by surface-acoustic waves. In the limit of droplets with small equilibrium contact angles the results of our Finite-Element technique are compared to results of a lubrication approximation model.

CPP 24.3 Thu 17:00 P2

Hydrodynamic interactions in Brownian ratchets — •Andrej Grimm and Holger Stark — Universität Konstanz, Fachbereich Physik, 78457 Konstanz

Brownian ratchets are often used as model systems for molecular motors such as kinesin and myosin [1]. These proteins always work in an aqueous enviroment. It has recently been shown that hydrodynamic interactions play an important role and lead to a novel type of dynamics of colloidal particles driven by a tilted sawtooth potential [2]. Using Brownian dynamics simulations, we study the influence of hydrodynamic interactions on Brownian ratchets. We consider particles in toroidal traps moving under the influence of an on-off sawtooth potential. Our objective is to investigate how the velocity of the particles depends on the relevant parameters of the potential and on the particle density.

[1] F. Jülicher, A. Ajdari, J. Prost, Rev. of Mod. Phys. **69**, 1269 (1997)
[2] C. Lutz, M. Reichert, H. Stark, C. Bechinger, cond-mat/0510135 (2005)

CPP 24.4 Thu 17:00 P2

Wettability-control of droplet deposition and detachment — •Jean-Christophe Baret[1] and Martin Brinkmann[2] — [1]Institut Charles Sadron, 6, rue Boussingault, F-67083 Strasbourg, France — [2]Max-Planck-Institut for Dynamics and Self-Organization, Bunsenstr. 10 D-37073 Goettingen, Germany

The conditions for droplet deposition on a plane surface are studied using the electrowetting effect to continuously modulate the substrate wettability. Droplets of various volumes attached to the tip of a pipette are brought into contact with the surface. When pulled up the droplets are deposited at sufficiently small contact angles and large volumes or completely detach from the substrate at small volumes and large contact angles. We demonstrate that electrowetting on dielectric (EWOD) provides an ideal tool to systematically study capillary instabilities involving a free contact line. The experimental limit between deposition and detachment in the contact angle/volume plane is in good agreement with analytical and numerical predictions obtained within the capillary model. In the case of zero buoyancy, the droplet contour can be expressed in terms of elliptic integrals which allows to derive an approximate expression for the droplet volume at the transition between the two modes of instability. This criterion can be applied in technological processes which involve the production and placement of small droplets, e.g., in spotting arrays of biomolecules or in microcontact printing.

CPP 24.5 Thu 17:00 P2

Wetting random assemblies of cylindrical rods — •Martin Brinkmann — Max-Planck-Institut for Dynamics and Self-Organization, Bunsenstr.10, D-37073 Goettingen, Germany

The mechanical properties of loose random assemblies of rigid rods undergo a significant change when a liquid phase is dispersed in between the bodies. In experiments a strong tendency to form bundles of rods is obseverd. The anisotropic capillary interaction between cylindrical rods can be obtained from numerical minimizations of the interfacial energy and, for elongated liquid states, computed in an analytical model. As the relative tilt angle α of the cylinders tends to zero the liquid spreads between the two clyinders. If the surfaces are in contact the wetted length L and the capillary torque T diverge as $L \propto \alpha^{-\xi}$ and $T \propto \alpha^{-(\xi+1)}$, respectively, for hydrophilic contact angles $\theta < \pi/2$. As predicted from the analytical model and confirmed by numerical minimizations one has $\xi = 1$ if the Laplace pressure of the bridge is prescirbed while $\xi = 3/4$ if the volume of the liquid of bridge is fixed. In the latter case, one finds a discontinuous transition between droplets localized at the contact point for $\alpha \approx 1$ and elongated liquid filaments for small tilt angles $\alpha \ll 1$. The capillary force F between the cylinders is studied for a variety of fixed tilt angles including the particular cases $\alpha = \pi/2$ and $\alpha \ll 1$.

CPP 24.6 Thu 17:00 P2

Wetting Morphologies in Triangular Grooves — •Krishnacharya Kareh[1], Martin Brinkmann[1], Evgeny Gurevich[1], Bruce Law[2], Stephan Herminghaus[1], and Ralf Seemann[1] — [1]MPI for Dynamics and Self-Organisation, Bunsenstr. 10, D-37073 Göttingen, Germany — [2]Kansas State University, Department of Physics, 327 Cardwell Hall, Manhattan, KS 66506, USA

We studied the wetting behavior of liquids in triangular grooves with chemically homogeneous walls. The length scale has been chosen to be small compared to the capillary length in order to avoid gravitational effects, but large enough for long range wetting forces (such as the van der Waals force) to be irrelevant. Droplets form elongated morphologies with negative mean curvature for contact angles smaller than 90deg minus half the opening angle of the groove. For larger contact angles, the liquid either forms elongated filaments of finite length and positive mean curvature or drop-like morphologies. For in situ manipulation of small amounts of liquid on this substrate topography (open microfluidics), we used electrowetting. We could vary the contact angle of the liquid on the substrate as a function of the applied Voltage. The filling and drainage behavior of these grooves were studied as a function of time and contact angle. In contrast to grooves with rectangular cross section, the liquid filaments in triangular grooves undergo a dynamic instability when being quenched from a filling to a non-filling situation. The liquid filament breaks up into isolated droplets with a preferred distance which compares favorably with a straightforward theoretical

CPP 24.7 Thu 17:00 P2

Digital Microfluidics with Monodisperse Gel Emulsions — •Ralf Seemann, Craig Priest, and Stephan Herminghaus — MPI for Dynamics and Self-Organization, Bunsenstr. 10, D-37073 Göttingen, Germany

Microfluidics usually involves single phase liquids transported through microchannel networks. Instead of single phase flow, we have employed monodisperse emulsions to compartment liquids for microfluidic processing. If the volume fraction of the continuous phase is very low, the dispersed compartments (droplets) assemble into well-defined arrangements, analogous to foam. Hence, the position of a single droplet with a certain chemical content within an ensemble of droplets is fully determined while being transported through microfluidic channels. We demonstrate a one-step, in situ method for the production of monodisperse gel emulsions, suitable for microfluidic processing [1]. A variety of channel geometries is employed for positioning, sorting, dividing and exchanging droplets in 'lab-on-chip' style processing. Furthermore, we have selectively induced coalescence to initiate chemical reactions between adjacent compartments. Our method is well-suited for applications in combinatorial

chemistry, DNA sequencing, drug screening, and protein crystallization.

[1] C. Priest, S. Herminghaus, and R. Seemann, Appl. Phys. Lett. (in press)

CPP 24.8 Thu 17:00 P2

Monodisperse Emulsions Confined in Channels — •Enkhtuul Surenjav, Magdalena Ulmeanu, Craig Priest, Dmytro Melenevsky, Stephan Herminghaus, and Ralf Seemann — MPI for Dynamics and Self-Organization, Bunsenstr. 10, D-37073 Göttingen, Germany

Emulsion droplets with diameter in between 2 and 20 microns provide suitable compartments for very small quantities of solvents or reagents. We present a comparative study of several techniques for the preparation of monodisperse emulsions. For some preparation techniques, the continuous phase of the emulsion has to be reduced subsequent to the preparation. It exhibits a variety of transitions in its topology upon interaction with an externally provided geometric constraint or applied field. This is demonstrated, e.g., using an organic ferrofluid as continuous phase and an inhomogeneous applied magnetic field. Furthermore, we study the formation of 2D and 3D emulsion crystals by mixing droplets with two distinct diameters with a certain size ratio, which may lead to a novel type of chemical reaction setup and new materials.

CPP 24.9 Thu 17:00 P2

Wetting properties of nanostructured composite surfaces and patterning of monolayer and polymer surfaces — •Oliver Bäumchen, Renate Fetzer, and Karin Jacobs — Experimental Physics, Saarland University, D-66123 Saarbrücken, Germany

Two main factors influence the wettability of a surface: On the one hand there is chemical heterogeneity (e.g. coatings or silane layers), on the other hand topographical roughness (surface structure) on the micro- and nanometer scale. Very rough surfaces can suspend small liquid drops and produce very large contact angles. Our goal is to fabricate and to characterize physically and chemically nanostructured surfaces. Moreover, we aim at characterizing the impact of microscopic local wetting properties to the macroscopic wetting behavior. By AFM, we study wetting at the nanoscale, whereas on the macroscale, we utilize optical microscopy. That way, we investigate a new nanocomposite material based on aluminum and its oxide [1], that exhibits complex topographical structures. In addition, we are interested in chemically structured surfaces and their wetting behavior. Therefore we utilize TEM masks to turn hydrophobic PDMS (poly(dimethylsiloxane)) films by plasma etching partially into hydrophilic silicone oxide-like layers. Furthermore we apply the microcontact-printing technique to pattern self-assembled thiol and silane monolayers on gold and silicon surfaces.

[1] M. Veith et al., Europ. J. Anorg. Chem. 24, 4387 (2003)

CPP 24.10 Thu 17:00 P2

Structured Micro- and Nanotubes for Microfluidic and Nanoprinting applications. — •Valerij Luchnikov and Manfred Stamm — Institut für Polymersforschung e.V. Dresden, Hohe Str. 6, 01069 Dresden

Tubes and pores of micro- and nanoscale dimensions find numerous applications in separation science, biotechnology, microfluidics, sensors. However possibilities of engineering tube-based devices are strongly limited by hard access to inner walls of the mesotubes. We surmount this problem by formation of tubes via rolling-up of strained bilayers released in controllable manner from a solid substrate [1]. In our fabrication scheme bending moment arises in the bilayer film, composed ot two chemically distinct polymers due to swelling of the bottom component of the bifilm upon immersion it in a selective solvent [2]. (For example, poly(4-vinyl pyridine)/polystyrole bilayer rolls up in acidic water due to swelling of P4VP). Before rolling, the bilayer can be exposed to variety of planar methods of surface modification, such as micro-contact printing, photolithography, plasma activation, magnetron metal sputtering, and others. Geometrically complex patterns (e.g. intermittent hydrophilic/hydrophobic regions) can be created atop of bilayer lithographically and then form patterned interiour of the tubes upon rolling. This opens new broad opportunities for design of mesotube-based devices and basic research.

[1] V.Ya. Prinz et.al. Physica E 2000, 6, 828

[2] V.A. Luchnikov, O. Sydorenko, M. Stamm, Adv. Mater. 2005, 17, 1177

CPP 24.11 Thu 17:00 P2

Polymer Droplets on Soft, Brush-Coated Substrates — •Torsten Kreer[1], Claudio Pastorino[2], Kurt Binder[2], and Marcus Mueller[3] — [1]Institut Charles Sadron, 6 rue Baussingault, 67083 Strasbourg Cedex, France — [2]Institut fuer Physik, WA331, Johannes-Gutenberg-Universitaet, 55099 Mainz, Germany — [3]Institut fuer theoretische Physik, Georg-August-Universitaet, 37077 Goetingen, Germany

Brushes are soft, elastically deformable substrates exhibiting a rich wetting behavior and additional dissipation mechanisms for the motion of droplets. We study thin polymer films and droplets on brushes by NEMD simulation using a DPD thermostat. The brushes consist of chemically identical polymers as the droplets.

The properties of the interface between the brush and the melt of identical molecules in equilibrium and under shear are dominated by universal entropic effects. Upon increasing the grafting density the free polymers are expelled from the brush and a brush-melt interface gradually builds up. Molecular conformations and the overlap between brush and melt are studied for different grafting densities. The slip length of the melt on the brush substrate is extracted from the velocity profiles and adopts large positive values for low grafting densities, but decreases and becomes negative for dense, autophobic brushes.

At high grafting density the polymer melt forms droplets (autophobic dewetting). Nanoscopic polymer droplets driven by volume forces (e.g. inclined plane or centrifugal forces) are investigated. The steady state at which the droplet moves at constant velocity is discussed.

CPP 24.12 Thu 17:00 P2

Nanoscale Flow-Cells and their Application — •Tilmann Rogge[1], Kristin Mandisloh[1], Timo Mappes[1], Martina Schürmann[2], Axel Rosenhahn[2], Ahmed Abdelmonem[2], and Michael Himmelhaus[2] — [1]Institut für Mikrostrukturtechnik, Forschungszentrum Karlsruhe, 76021 Karlsruhe — [2]Angewandte Physikalische Chemie, Universität Heidelberg, 69120 Heidelberg

Our goal is to study aqueous, organic, and biological liquid flows in micro- and nanochannels. Although liquid flows in micro- and nanocapillaries usually still can be treated within the framework of conventional continuum mechanics, the situation differs from that in macrosystems due to the smaller characteristic length scales, such as channel length and width, and the significantly increased surface-to-volume ratio of the fluid and its surrounding. Therefore, the balance between the various forces contributing to the overall behavior of the fluidic system is changed. Since the flow velocities are small, interface forces are an important contribution to the overall performance of microfluidic devices. We use pressure tight flow cells with optically transparent windows allowing for optical investigations with UV-, VIS- and IR radiation. The micro- and nanostructures are fabricated by X-ray lithography and other lithographic methods yielding channel widths of some hundreds of nanometers and channel heights below 10 micrometers. An appropriate periphery allows the use of flow volumes in the nanoliter range. Applications of these flow cells are adsorption studies with non-linear optical techniques. Furthermore, digital in-line holography is used to track tracer particles carried by the flow. The results are compared to those obtained by conventional microscopy.

CPP 24.13 Thu 17:00 P2

Thin-film field-effect-transitors for liquid movement detection in microfluidic systems — •Pagra Truman, Petra Uhlmann, and Manfred Stamm — Leibniz-Institut für Polymerforschung Dresden e.V., Hohe Str. 6, 01069 Dresden, Germany

In microfluidic Lab-on-Chip systems and for applications in fundamental research there is a high demand for cost efficient minimal invasive massive parallel highly sensitive liquid movement detection with high spatial resolution. Currently available techniques like optical observation, scattering techniques or scanning techniques do not fulfill all requirements. Therefore we develop a new thin-film Field-Effect-Transistor based detection scheme where single transisitor devices measure flow speed and filling level of capillaries besides being capable to analyze liquid properties like ionic strength. We present electrical transport measurements on large-scale transistor structures based on Silicon-on-Insulator (SOI) technology in aqueous solutions. Planar thin-film Silicon source-drain layers with lateral dimensions of few mm times few centimeters were laterally patterned out of the 55 nm thick top Silicon layer by standard circuit board lithography and wet chemical etching. The devices were electrically connected via metal contacts evaporated on such layers. Af-

ter integration into a microfluidic cell the latter was utilized to perform the previously described sensing operations.

CPP 24.14 Thu 17:00 P2

An experimental setup to handle liquids in a nanofluidic device — •Evelyn Meyer and Hans-Georg Braun — Leibniz Institute of Polymer Research, Max-Bergmann Center of Biomaterials, D-01069 Dresden, Hohe Strasse 6

The manipulation of fluids of femto- to picoliter volume in micro or nanosized channels is realized by a piezodriven manipulation unit adapted to an inverse fluorescence microscope. A truncated PDMS pyramid with a basal plane of 20 to 400 micrometer is mounted to a piezomotor system and can be controlled in x,y,z direction and enables filling and sealing of an underlying micro-and nanochannel structure .This assembly allows the encapsulation of DNA molecules for dynamic studies in confined geometries. The success of the filling process depends on the wettability of the microstructured surface according to the Wenzel regime for wetting of rough surfaces. Using an adjustable slit geometry between pyramid and substrate fluids entrapped in the slit can be transported along a substrate with controllable velocity to study the behaviour of propagating fluids on chemical and topographical heterogenous surfaces.

CPP 24.15 Thu 17:00 P2

Integrated peristaltic pumps tailored for new migration phenomena — •Stefan Gerkens, Dario Anselmetti, and Alexandra Ros — Experimental Biophysics & Applied Nanosciences, Bielefeld University, Department of Physics, Universitaetsstrasse 25, 33615 Bielefeld, Germany

Peristaltic pumps based on PDMS can be used as fluidic driving-mechanism for a fully-integrated lab-on-a-chip evading difficulties involved with electrokinetic approaches. The characteristica of such a device are well suited for a large variety of microfluidic applications, for example the transport of biological compounds or colloidal particles. The fabrication is possible by soft lithography requiring only two PDMS moulds. External control is performed by an array of digitally assessable microvalves providing the necessary pressure for actuation. Both the lithography process (e.g. channel geometry) and the parameters controlling the external microvalves (e.g. actuation pressure and valve sequence) yield a large possibility to optimize the micropump for different problems. In this contribution, the application of a fully PDMS based peristaltic pump for the driving of colloidal particles in microfluidic networks is presented. Characterisation of this setup will be carried out in terms of flow rates, periodic driving amplitudes and single pumping-cycle analysis. This microfluidic pump will be used for the development of new migration phenomena in tailored microfluidic devices.

CPP 24.16 Thu 17:00 P2

Simple Method for the Stretching and Alignment of Single Adsorbed Synthetic Polycations — •Vera Bocharova[1], Anton Kiriy[1], Manfred Stamm[1], Francois Stoffelbach[2], Robert Jérôme[2], and Christophe Detrembleur[2] — [1]Leibniz Institute of Polymer Research Dresden, D-01069 Dresden (Germany) — [2]Center for Education and Research on Macromolecules (CERM), University of Liege, Sart-Tilman, B6, 4000 Liege, Belgium

It was found that positively charged macromolecules co-deposited with octylamine (OA) onto mica appear in a considerably more stretched conformation compared to adsorption onto untreated mica. Furthermore, the molecular thickness is considerably larger whenever the macromolecules are co-deposited with OA, which indicates a change in the local conformations of the chains and the orientation of their side-groups with respect to the substrate. These observations can be explained by the formation of an ultra-thin liquid-like film of OA onto mica that decreases the surface energy, weakens the interactions of the macromolecules with the surface and allows them to be stretched. The contour length and molar mass for the stretched macromolecules can be directly measured. The increase in the molecular height in case of co-deposition with OA drastically improves the molecular resolution, makes even ultra-thin polycations detectable and thus extends significantly the range of objects, which can be involved in single-molecule experiments.

CPP 24.17 Thu 17:00 P2

Adsorption and desorption of solvents by periodic mesoporous organosilica of different pore sizes — •M.A. Schreiber[1], M. Güngerich[1], P.J. Klar[1], W. Heimbrodt[1], J. Morell[2], V. Rebbin[2], M. Fröba[2], T. Henning[3], L. Eichhorn[3], J.J. Brandner[3], and K. Schubert[3] — [1]Dept. Physics and WZMW, Philipps-University of Marburg, Germany — [2]Institute of Inorganic and Analytical Chemistry, Justus-Liebig-University, Gießen, Germany — [3]Forschungszentrum Karlsruhe, IMVT, Eggenstein-Leopoldshafen, Germany

Periodic mesoporous silica (PMOs) are organic-inorganic hybrid materials with regular pore systems and well defined pore sizes in the range of 3 to 15 nm yielding inner surfaces of about 1000 m^2/g. The organic units in the pore walls are two-point attached within the silica matrix through covalent bonds and therefore are homogenously distributed and a genuine part of the 3D pore wall framework. The choice of the organic functionalisation is very versatile making these hybrids interesting for applications in catalysis and micro-reactor technology. Here we study the adsorption and desorption behaviour of the solvents ethanol and benzene by benzene-functionalized and ethane-functionalized PMOS with different pore sizes in the temperature range between 20 and 140 °C by Raman spectroscopy. We find significant differences in the adsorption-desorption behaviour for different solvents as well as for different pore sizes suggesting that PMOs make a selective separation of solvent vapours possible.