CPP 34: Microfluidics I: Applications and Devices

Time: Thursday 9:30–12:30 Location: ZEU 160

CPP 34.1 Thu 9:30 ZEU 160

Ship-in-a-Bottle Assembly of Linked Geometrically Coupled Microdevices — •Tobias Sawetzki[1], Sabri Rahmouni[1], David W.M. Marr[2], and Clemens Bechinger[1,3] — [1]2. Physikalisches Institut, Universität Stuttgart — [2]Chemical Engineering Department, Colorado School of Mines, Golden — [3]Max-Planck-Institut für Metallforschung, Stuttgart

To realize complex microfluidic systems the ability to drive and control the single components in an integrated and cooperative fashion is required. In current mircofluidic chips the actuation and manipulation of individual units is often done on a single-device level by applying macroscopic methods such as external pressure. The need for connections to the macroscopic world for every single device on the chip hinders both, the portability and the development of highly complex architectures on Lab-on-a-Chip systems. We present a new method [1] to build, actuate and control microfluidic systems with only one external source of power. Magnetic fields are not only used to *in-situ* assemble paramagnetic colloidal particles in confining geometries, but also to power the components non-invasively and massively parallel. By combining local geometry of channel architecture with this single global field, the functionality of a constituent device is only defined by the shape of colloidal cluster and surrounding. Applying this method, we present a full set of basic microfluidic components like pumps, valves and mixers, and demonstrate that more complex operations can be performed by linking individual units together.

[1] Sawetzki *et al.* PNAS, Dec. 08

CPP 34.2 Thu 9:45 ZEU 160

Separation of magnetic beads by a combination of magnetic and hydrodynamic forces — •Frank Wittbracht, Alexander Weddemann, Alexander Auge, and Andreas Hütten — Universität Bielefeld, Universitätstraße 25, D-33615 Bielefeld

Lab-on-a-chip technologies have gained importance in recent years. The integration of all functions and components needed for the analysis of a sample on microfluidic chips has to be achieved. Magnetic materials are widely used in these systems for various applications such as magnetohydodynamic pumps and valves. Especially in terms of separation and detection of biological samples magnetic materials are suitable.

In this work a microfluidic separation system for magnetic beads is experimentally realized according to theoretical simulations. The separation of magnetic beads is achieved by magnetic gradient fields resulting from conducting lines near the microfluidic channel. Experimental results are compared to calculated results.

CPP 34.3 Thu 10:00 ZEU 160

Manipulation of nanoparticles by turbulent electrohydrodynamic flows — •Michael Boettcher, Magnus Jaeger, and Claus Duschl — Fraunhofer Institute for Biomedical Engineering (IBMT), Am Muehlenberg 13, 14476 Potsdam, Germany

Several methods for the manipulation of micro- and nanoparticles have attracted interest in medicine and biotechnology. Especially, lab-on-chip systems (LOC) found their applications due to their fine fluid channels being of the same length scale as the objects under test. An attribute of these micrometre-sized channels is a continuous fluid flow. In conventional LOCs these flows are often generated by external pressure-driven pumps. A alternative path to establish a fluid transport is a high-frequency, electrical travelling wave. This mechanism can be integrated directly into the chip and works without any moving parts. To this end, an array of parallel electrode elements provides the driving, electrical field. Under special circumstances, the induced fluid flow is accompanied by vortices above the electrodes. The establishment of these turbulent flows in our microfluidic device - which is defined by small Reynolds numbers and, therefore, a laminar flow - indicated a potential of the system for a new application. Our goal is to optimise these vortices to manipulate especially nanometre-sized particles e. g. viruses. For that it is essential to get a better understanding of the vortices. We use the travelling wave mechanism to accumulate artificial, fluorescent beads. The advantage of our system is the defined accumulation of nanometre-sized particles in the absence of any filtering material.

CPP 34.4 Thu 10:15 ZEU 160

Static and dynamic surface-coatings in quartz crystal- and Poly(dimethylsiloxane)-microfluidic channels — •Martina Everwand, Jan Regtmeier, and Dario Anselmetti — Bielefeld University, Experimental Biophysics & Applied Nanoscience, Universitätsstr. 25, 33615 Bielefeld, Germany

For bioanalytical applications, the surface properties of the Lab-on-a-Chip device are of great relevance, e.g. for limiting the band broadening in electroosmotic flow applications.

Therefore we have investigated three different coatings Poly(L-lysine)-poly(ethylene glycol) (PLL-PEG), F108 and n-Dodecyl-D-Maltoside Methyl Cellulose (DDM-MC)) in quartz-crystal and Poly(dimethylsiloxane) (PDMS) microfluidic systems with respect of their electroosmotic flow, protein adhesion and contact angle properties. We used either statical or dynamical coating, where the polymers were incubated and rinsed prior usage or where the polymers were directly added to the separation solution.

In summary, all three coatings were able to reduce the electroosmotic flow and protein adsorption in quartz as well as in Poly(dimethylsiloxane) microchips. The highest reductions were obtained for the dynamically coated n-Dodecyle-Maltoside Cellulose polymer.

CPP 34.5 Thu 10:30 ZEU 160

Internal flow and surfactants' dynamics in confined emulsions — •Audrey Steinberger[1], Ralf Seemann[1,2], and Stephan Herminghaus[1] — [1]MPI for Dynamics and Selforganization, D-37073 Goettingen — [2]Experimental Physics, Saarland University, D-66041 Saarbruecken

We study the flow of emulsions confined in microchannels whose lateral dimensions are on the same scale as the size of the drops. This system is not only a promising tool for handling liquids in microfluidic processes but also a convenient model system to study the dissipation mechanisms associated to the flow of confined emulsions. Interfacial friction induces a recirculation flow -controlling the mixing- within the droplets. Our aim is to investigate the interaction between those internal flows and the dynamics of the surfactants used to stabilize the emulsion: what is the effect of the viscous stress on the surfactants' layer that surrounds the drops and stabilizes the emulsion? Reciprocally, what is the impact of the surfactants' frictional properties significantly on the internal flow? And what happens in very concentrated emulsions, where the thickness of the continuous phase lamellas separating the drops becomes very small, and possibly reduces to a surfactant bilayer?

To answer those questions, we have developed a micro-PIV setup that allows us to measure simultaneously the velocity field within the drops and the local concentration of fluorescent surfactants on two separate color channels. Here we describe this setup and report on the first results we obtained with it.

15 min. break

CPP 34.6 Thu 11:00 ZEU 160

Phase Transition Behaviour of Nanopore Confined Liquids explored by Capillary Rise Experiments — •Simon Gruener and Patrick Huber — Saarland University

We present measurements on the capillary rise (spontaneous imbibition) of liquids into silica monoliths (porous Vycor) permeated by tortuous pores with radii of about 5 nm. The flow properties are studied as a function of the complexity of the building blocks of the liquids (water, n-alkanes and liquid crystals). In this talk I will present measurements that permit detailed insights into the phase transition behaviour of selected liquids during the imbibition process. First and foremost I will focus on the well-known surface freezing effect in tetracosane. Because of the striking impact of this phenomenon on the surface tension of the liquid the capillarity driven imbibition process is perfectly suitable for such examinations. This work has been supported within the DFG priority program 1164, Nano- & Microfluidics (Grant No. Hu 850/2).

CPP 34.7 Thu 11:15 ZEU 160

Focusing X-ray beam by dynamic compound refractive lenses in a microfluidic device — •Yasutaka Iwashita[1], Chris-

tian Bahr[1], Ralf Seemann[1,2], and Stephan Herminghaus[1] — [1]MPI for Dynamics and Self-Organization, D-37073 Goettingen — [2]Experimental Physics, Saarland University, D-66041 Saarbruecken

Compound refractive lenses (CRL), composed of a large number of individual lenses of small radii in a row embedded in a solid medium, have been developed as X-ray lenses [1]. To broaden the possibilities and functions of CRL's, we designed a 'dynamic CRL' composed of gas bubbles in a liquid, where the bubbles are generated *in situ* and flowing consecutively in a microfluidic device. Here, the lamellae between the bubbles act as lenses. Due to the continuous renewal of the materials, this system leads to a high stability against high X-ray intensities. Furthermore, the variation of bubble shape controlled via flow parameters allows *in situ* optimization of the optical properties.

We generate dynamic CRL structures with gas - octadecane foams stabilized by surface freezing and gas - dodecylcyanobiphenyl (liquid crystal) foam stabilized by surface ordering. The advantages of these systems are high X-ray transmittance and stabilization without surfactants. As an example, the theoretically estimated lens properties of a generated dynamic foam, i.e., the focal length, gain and transmittance along the optical axis, were 97.7 μm, 1800 and 50.3 %, respectively, for X-ray energy of 8 keV.

[1] A. Snigirev, V. Kohn, I. Snigireva and B. Lengeler, *Nature* 384(6604), 49(1996).

CPP 34.8 Thu 11:30 ZEU 160

Stability and transitions of droplet arrangements confined in microchannels — •Enkhtuul Surenjav[1], Julia Burkhardt[1], Martin Brinkmann[1], Stephan Herminghaus[1], and Ralf Seemann[1,2] — [1]MPIDS, Göttingen, Germany — [2]Experimental Physics, Saarland University, Saarbrücken, Germany

We focus on organization and manipulation of monodisperse gel emulsions in microchannels both in dynamic and static droplet arrangements. Transitions between certain foam-like topologies in an emulsion flowing through a channel can be induced e.g. by varying the geometry of the channel. Due to the finite energy required to change a certain droplet arrangement ("T1"-Transition) topology transitions are inherently hysteretic and depend not only on the droplet size but also on the volume fraction of the dispersed phase. By incorporating corners into the microfluidic channel network we performed precise manipulation of the individual droplet positions with respect to the neighboring droplets. The number of phase shifts as a function of drop size, volume fraction and corner angles were studied and show reasonable agreement with the theoretical consideration based on the path length differences. In stopped flow conditions, quasi two-dimensional structural transitions of static emulsion topologies have been studied as a function of lateral force. By applying a lateral force to the static droplet arrangement, we could vary the equilibrium conditions of different arrangements due to the variation of dispersed phase volume fraction during the droplet compression. We compared the experimental results with the numerical calculation and found qualitative agreement.

CPP 34.9 Thu 11:45 ZEU 160

Microfluidic Physics of Self-synchronizing Picolitre Droplet Generation — •Venkatachalam Chokkalingam[1], Stephan Herminghaus[1], and Ralf Seemann[1,2] — [1]Max Planck Institute for Dynamics and Self-Organization, Goettingen, Germany. — [2]Experimental Physics, Sarland University, Germany.

The in-situ generation of pairs of droplets with excellent monodispersity is essential for quantitative (bio-) chemical reactions in a droplet based microfluidic chip. In the presented work we demonstrate the simultaneous, self-synchronized production of droplets with high dispersed phase volume fraction (up to about 96 %) and excellent monodispersity (variance of the droplet diameter < 1.2 %) with two different contents by step emulsification. The synchronization is achieved by a pressure cross talk of two connected production units while retaining all relevant properties of a single step-emulsification unit. Pairs and triplets of droplets can be achieved. While the drop volumes of the two droplet types may be different up to a factor of two, the excellent monodispersity of each type is retained.

CPP 34.10 Thu 12:00 ZEU 160

Promoting selective gold immobilization onto polymer nanotemplates using solution flow-stream technique — •Ezzeldin Metwalli[1], Jean-Francois Moulin[2], Jan Perlich[1], Weinan Wang[1], Alexander Dieter[1], Stephan V. Roth[3], and Peter Müller-Buschbaum[1] — [1]TU München, Physik Department LS E13, James-Franck-Str.1, 85747 Garching, Germany — [2]FRM II, TU München, 85747 Garching, Germany — [3]HASYLAB at DESY, Notke Str. 85, 22603 Hamburg, Germany

Guiding gold nanoparticles aggregation into an ordered nano-patterned structure has attracted an immense attention due to applications in nanoelectronics, bioelectronics, and gas sensors. In the current investigation, gold nanoparticles were cast onto nanostructured polymer templates using solutions subjected to hydrodynamic flow by utilizing a simple flow device. Phase-separated polystyrene-block-polyethylene P(S-b-E) diblock copolymer film with parallel cylinder morphology is selected as a nanostructured polymer template. Using in situ grazing incidence small angle X-ray scattering (GISAXS), the progressive gold deposition from solution at various flow rates onto the polymer template attached to the X-ray transparent flow-channel is investigated. The continuously flowing stream of gold solution causes a systematic increase of the X-ray contrast between both phase-separated blocks of the block copolymer template indicating a flow-induced selective gold immobilization. With further gold nanoparticles upload by the continuous flow, the selectivity characteristic of the flow deposition method diminishes with the formation of an almost uniform gold layer.

CPP 34.11 Thu 12:15 ZEU 160

Lattice Boltzmann studies of finite size driven droplet evaporation and droplet dynamics — •Fathollah Varnik — Interdisciplinary Center for Advanced Materials Simulation, Ruhr University Bochum, Germany

The lattice Boltzmann (LB) method has received growing interest both in the scientific and the engineering community. Significant extensions and ramifications of the LB method have been proposed allowing the study of a rich variety of fluid dynamics problems such as the flow through porous media, two phase flows [1] as well as roughness effects on transitional flows [2], to name just a few.

The lattice Boltzmann method proves itself as a particularly powerful tool when it comes to a study of intricate boundary conditions such as chemical and topographical heterogeneity [3].

Here, the method is applied for a study of interesting issues such as instability (evaporation) of droplets in a system with a finite size as well as to the dynamics of droplets.

[1] X. Shan and H. Chen, Phys. Rev. E 47, 1815 (1993); and Phys. Rev. E 49, 2941 (1994); M. R. Swift, W. R. Osborn, and J. M. Yeomans, Phys. Rev. Lett. 75, 830 (1995); and A. J. Briant, A. J. Wagner, and J. M. Yeomans, Phys. Rev. E 69, 031602 (2004).

[2] F. Varnik, D. Dorner, and D. Raabe, J. Fluid Mech. 573, 191 (2007); F. Varnik and D. Raabe, Modell. Simul. Mater. Sci. Eng. 14, 857 (2006).

[3] F. Varnik, P. Truman, Bin Wu, P. Uhlmann, M. Stamm, D. Raabe, Phys. Fluid. 20, 072104 (2008).